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Effects of Exposure to Noise on Mental Performance and Emotional Well-Being of Students in a School in Kaduna, Nigeria

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ABSTRACT

The study investigated exposure to noise, mental performance, and emotional wellbeing of students. Two simultaneous field experiments were performed each day for five days. At each experiment, 30 students completed mathematics and English language tasks in a quiet 38 dBA classroom called, Exposure I (ExpI). Simultaneously, another 30 students completed the same mathematics and English language tasks in a noisy 75 dBA classroom, called Exposure II (ExpII). After the tasks were completed, the students were asked to rate their perceptions of annoyance and task dificulty with respect to the noise levels in the two experimental classrooms. Independent samples t-tests and Welch's test were used to analyse the data. Results from the data analysis showed that, in comparison to ExpI (38 dBA), the performance of mental tasks related to mathematics was significantly affected in ExpII (75 dBA). There was no signfcant effect found in the mental performnce related to the English language task between ExpI (38 dBA) and ExpII (75 dBA). Furthermore, the results from this study showed that the students were signficantly annoyed in classroom with a noise level of 75 dBA. The results from this study suggest that mental tasks can be much more difficult in noisy classrooms. The study highlights the critical need for architects and policymakers to prioritise acoustic considerations in school design and renovation.

Keywords: Classrooms, field experiments, mental performance, noise, students.

INTRODUCTION

Background

Noise is a pervasive environmental issue in schools, particularly in urban areas that lack basic infrastructure to mitigate noise. Widely, numerous published works indicate the detrimental effects of high level of noise on students' mental performance and well-being (Hygge, et al., 2002; Shield and Dockrell,2003; Standfeld et al.,2005; Smith & Dockrell, 2008; Stanfeld & Clark 2015; Caviola et al., 2021; Clark et al., 2021; Gheller et al., 2023). However, the key concerns in this present study are two: First, literature suggests that the effects of noise on mental performance and well-being have been studied extensively globally. Second, there is paucity of empirical evidence on the effects of noise on performance and well-being of school children in Nigeria. Second, to date, many schools in Nigeria seems to lack adequate strategies to mitigate the effect of noise such as the use of sound proofing or noise-reducing strategies and policies. In view of these concerns,this study aims to examine the effects of noise on mental performance and emotional well-being of students at a school in Kaduna, North-western, Nigeria. The results from this study contribute to the growing body of research on the impact of noise on cognitive performance of students and their well-being. The results also have implications for policy and practice in Nigerian schools in terms of reducing the effects of noise and promoting a healthier learning environment.

LITERATURE REVIEW

Issues related to noise and poor acoustic design across educational buildings have been well established (Shield, 2012). When it comes to schools, noise is often generated from two main sources. First, external noise, which is noise from the physical environment, such as road traffic noise. Second, internal noise, such as noise from the school children as well as the equipment in the classroom (Smith and Dockrell, 2008). Previous

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research evidence from two different early studies conducted in the UK and USA respectively, has shown that internal and external noise have effects on pupils' academic performance and their emotional well-being (Crook & Langton, 1974; Cohen et al., 1980). Additionally, a 2006 study compared the performance of 158 children from six classes in four schools under two noise conditions while they performed some tasks. The two conditions are quiet and classroom babble. The results from the study indicated that the children in the babble condition performed significantly less well than children in the quiet condition (Dockrell and Shield, 2006). Moreover, similar studies found a poor correlation between noise levels above 70dBA and mathematics and reading task. (Connolly et al., 2016; Connolly et al, 2017).

A 2021 study linked the detrimental effect of classroom noise to the performance of moderately difficult mathematics task by children. The authors concluded that different types of environmental noise negate the performance of children (Caviola et al., 2021). Indeed, the results from a meta-analysis found that the performance of reading comprehension can decrease by 4% for a 1dB increase in aircraft noise. The study also found a linear relationship between aircraft noise and hyperactivity score (Clark et al.,2021). In another context, research has shown that mental performance as well visual and auditory attention is significantly reduced at high noise level of 95dBA (Jafari et al., 2019).

Loud external noise from large transportation inventions can affect both physical orientation and auditory senses. For example, a cross-sectional study which examined the relationship between aircraft noise, road traffic noise and reading comprehension in three countries of the Netherlands, Spain and United Kingdom found that aircraft noise was linearly associated with impaired reading comprehension (Stansfeld et al., 2005). The results are consistent with a study that assessed the pre-reading skills of pre-school children. The results indicate that pre-reading skills were significantly lower in classrooms with loud noise. Conversely, the children in the quieter classroom outperformed those children in the noisier classroom on the letter-number recognition task (Maxwell and Evans, 2000).

A noisy environment can impede language development, reading comprehension and memory recall (Kjellberg, 2000). Lundquist et al.(2000) found a poor correlation between mathematics scores, perceived annoyance, and noise have been reported, these results were obtained when they investigated the relationship between perceived annoyance, academic task and noise with 216 Swedish students. Moreover, annoyance has been shown to increase linearly with noise and noise has a greater influence on the performance of complex cognitive task than simple task (Zhang and Ma, 2022). In contrast, a 2023 study found mixed results regarding the effect of noise on children's performance. The authors noted that the effect of noise on children's performance is not always clear, implying that children can still perform better on attention and inhibition tasks under a relatively noisy environment (Gheller et al., 2024). Previous studies have linked some emotional distress, e.g., anxiety, decreased motivation, and aggression with noisy environments (Hygge, 2003; Bistrup, 2015).

Thus, a better understanding of how noise factor may affect performance tasks of school children, particularly in a different cultural and environmental context is needed in such settings. In general, noise has the potential to affect children's academic performance as well as their wellbeing.

METHOD

The school, geographic context of study and students

The study was conducted at a private school on a relatively large site on the outskirts of Kaduna, with ethical permision from the school authorities and parental consent to participate. Kaduna is the capital city of Kaduna state, Nigeria, (Figure 1). The school was purposely selected for the study because it is located in a quiet neigbourhood with classroom noise levels ranging from 35 to 38 dBA. However, 35 dBA is the standard noise level for classrooms (WHO 1999). The study included 60 students between the ages of 12 and 13, who were divided equally into two groups. The first group was named Exposure I (ExpI), while the second group was named Exposure II (ExpII). ExpI is the quiet (38dBA) classroom condition in this study and ExpII is the noisy (75dBA) classroom. See Figure 4 for some of the physical features of the classroom.

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Figure 1. Map of Nigeria Showing Kaduna State, the Study Area

Rationale for the research method

Ths study used experimental research method, which is the method commonly used to determine if one factor has an effect on another (Hakim, 2000; Creswell, 2012). Specifically, instead of using the laboratory research method, the field experimental research method was used for the study in order to conduct the experiment with the students in their natural (real) learning environment. Field experiments can provide a more robust and applicable findings when conducted in natural environments (Harrison and List, 2004; Levitt and List, 2007).

The procedure

The study was conducted as a series of field experiments for 5 days (Monday-Friday). Each field experiment lasted 90 minutes,ninety minutes correspond to the time the first two morning lesson periods in the school. Mornings were chosen for the field experiments for the sake of thermal comfort of the students. At each field experiment, the students were randomly assigned to either a classroom with low (ambient classroom) noise level of 38 dBA(ExpI or high (artificial classroom) noise level 75 dBA (ExpII).The noise level of 75 dBA is similar to road traffic noise and was artificially generated from a loud speaker hung in the ceiling at the middle of the classroom. The classrooms used for the experiments are similar in design, the distance between the classrooms is approximately 150 meters. Table 1 summarises a model schedule used to conduct each of the field experiment for 5 school days (Monday-Friday).

Table 1. Model of the schedule used to conduct each field experiment.

Time	**ExpI (38dBA) ambient classroom noise (8am-10am)**	**ExpII (75dBA)Artificial noise similar to road traffic (8am-10am)**
8.00am-8.10am	Briefing of participants	Briefing of participants
8.10am-9.40am	Performance of Mathematics and English language task for 90 minutes.(45minutes for mathematics and 45 minutes for English language)	Performance of the same Mathematics and English language task for 90 minutes.(45minutes for mathematics and 45 minutes for English language)
9.40am-9.50am	Questionnaire survey of annoyance and task difficulty	Questionnaire survey of annoyance and task difficulty
9.50am-10.00am	Comments and closing remarks for the day	Comments and closing remarks for the day

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Performance measure

The first experimental group (ExpI) performed mathematics and English language tasks for 90 minutes in a classroom with noise level of 38 dBA. Concurrently, the second experimental group (ExpII) performed similar mathematics and English language tasks for 90 minutes in the classroom with noise level of 75 dBA. The mathematics and English language based tasks were similar to previous lessons taught and appropriate for the age of the participants. The mathematics task consisted of 45 multiple choice question, similarly the English language task consisted of 45 multiple choice questions.

Questionnaire survey of perceived annoyance and task difficulty

A questionnaire survey was conducted at the end the performance test at each field experiment. The questionnaire measured the level of annoyance of the students at the two noise levels (38 and 75 dBA).The questionnaire employed the visual analogue scale (Lundquist et al., 2000), and the scale is 100mm long. (See Figure 2).The students were asked to pinpoint a mark along the scale that corresponds to their perceived annoyance during the experiments. The partoccupants already received training on how to use the scale prior to the field experiments.

In addition, the questionnaire was used to measure the perception of the students as regards difficulty in carrying the academic task during the field experiments using a five point Likert scale and uses responses including “Much easier” “Somewhat easier”. “Neither easier nor harder”, “Somewhat harder”, and “Much harder”.

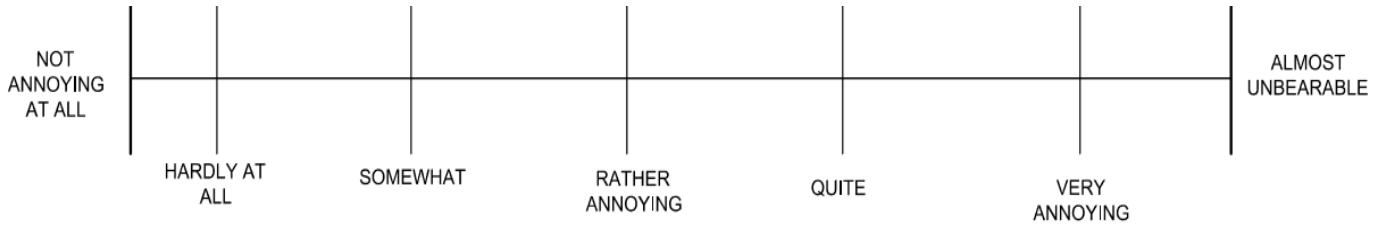

Figure 2. Visual analogue scale; Source: Lundquist et al. (2000)

Physical measurements

Several physical measurments were undertaken during the experiment, which include noise level, using CEM 8850 sound meter, indoor air temperature and Relative humidity was measured using Exitech 445815 thermo/hygrometer. $C0_2$ was measured using indoor $C0_2$ meter and daylighting was measured with YK-2005 Lux meter, Figure 3. All the physical measurments were taken at middle of the classroom at a height of 1.2 metres above the floor level.

Figure 3. Devices Used For Physical Measurments At The Field Experiments

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Statistical analysis

Both descriptive and inferential statistics were used to analyse the data from the field experiments using SPSS version 24. Normality test was conducted using Skew and Kurtosis test. Independent samples t-tests were used to determine differences in cases where the variance are equal and in cases where variance are not equal Welch's test was performed .The significance level was set at $p = 0.05$.

RESULTS

The participants, physical characteristics of the classrooms and indoor environmental measures

The study comprised 60 students aged 12 and 13 who had no history of hearing problems. The sixty students were randomly assigned to one of two groups: ExpI and ExpII, for a total number of 30 students per group. ExpI consisted of 16 Boys and 14 Girls while ExpII had 17 Boys and 13 Girls. Overall, there were 33 boys and 27 Girls.

Each classroom used for the field experiments is approximately $70m^2$ (7mx10m), with natural ventilation provided by cross ventilated windows. The classrooms are constructed with sandcrete hollow block walls, rendered with cement and sand, and internally finished with emulsion paint, as shown in Figure 4. The roof plane also consists of an asbestos ceiling, wooden trusses and aluminium roofing sheets .The average temperature in the classroom during the field experiments (Early November 2022) was 26 degrees Celsius with a relative humidity of 55%. The average value of the daylighting levels in the classroom is approximately 345 Lux, the C02 level is approximately, 550 pm.

Figure 4. Physical Features of The Classrooms Used for The Field Experiments

Normality test

The result of the normality test (Skew and Kurtosis) for the performance measures in mathematics and English language tests were less than -1and +1. This result suggests that the variance of the data are equal, thus, and independent samples t-test was used to analyse the data as regards performance task in mathemathics and English Language.

Also, result of the normality tests (Skew and Kurtosis) for data concerning peceived annoyance was higher than -1 and +1, this result suggests that the variance are not equal, therefore a Welch's test was used to analyse the data concerning perceived annoyance.

Performance

As regards mathematics task, the performance of the students in all five field experiments shows that the students in ExpI (38 dBA) was significantly higher (M =28.3, M =24.7), compared to students in ExpII,

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(p=0.018, t=2.43).This result shows that noise in classrooms can significantly affect the performance of students in mathematics based tasks.

Similarly for the English Language task, there was no significant difference observed between the performance of the students in ExpI, 38 dBA and ExpII, 75 dBA, (p=0.235, t-1.2). Although, the results show that the performance of the students in ExpI, 38 dBA was a little high (*M* =26.9) than students in ExpII, 75 dBA (*M* =25.1).

Annoyance effects

Table 2 shows the annoyance effects of the students over 5 days from the field experiments. As can be seen from Table 1, there is a consistent difference between the annoyance level of the students in classroom with noise level of 39 dBA and that of 75 dBA. Overall, the result suggests that the students in the classroom with noise level of 75 dBA were significantly annoyed during the performance test than the students who were exposed to noise level of 38 dBA, (p=0.000, t-233.6).

Table 2. Result From Visual Analogue Scale: Mean and (Standard Deviation) of Annoyance Level in Mm of the Students at Quiet (38dBA) and Noisy Conditions (75dBA).

Days of experiment	38 dBA	75 dBA
1	12.2 (2.0)	93.6 (7.6)
2	12.4 (2.3)	90.1(7.8)
3	10.9(2.0)	89.4 (8.0)
4	12.3(2.2)	93.8 (6.8)
5	11.3(2.2)	92.6 (7.6)
Mean	**13.2(5.3)**	**91.9(1.9)**

Perceived task difficulty

Figures 5 and 6 present how the students in EXPI (38 dBA) and EXPII (75 dBA) perceived the extent to which noise can affect their work in classrooms. From Figure 5, most of the students claimed that relatively low level noise in the classroom did not have any influence on their classwork. In contrast, results in Figure 6 suggest that relatively high level of noise in the classroom has the potential to affect schoolwork by students negatively.

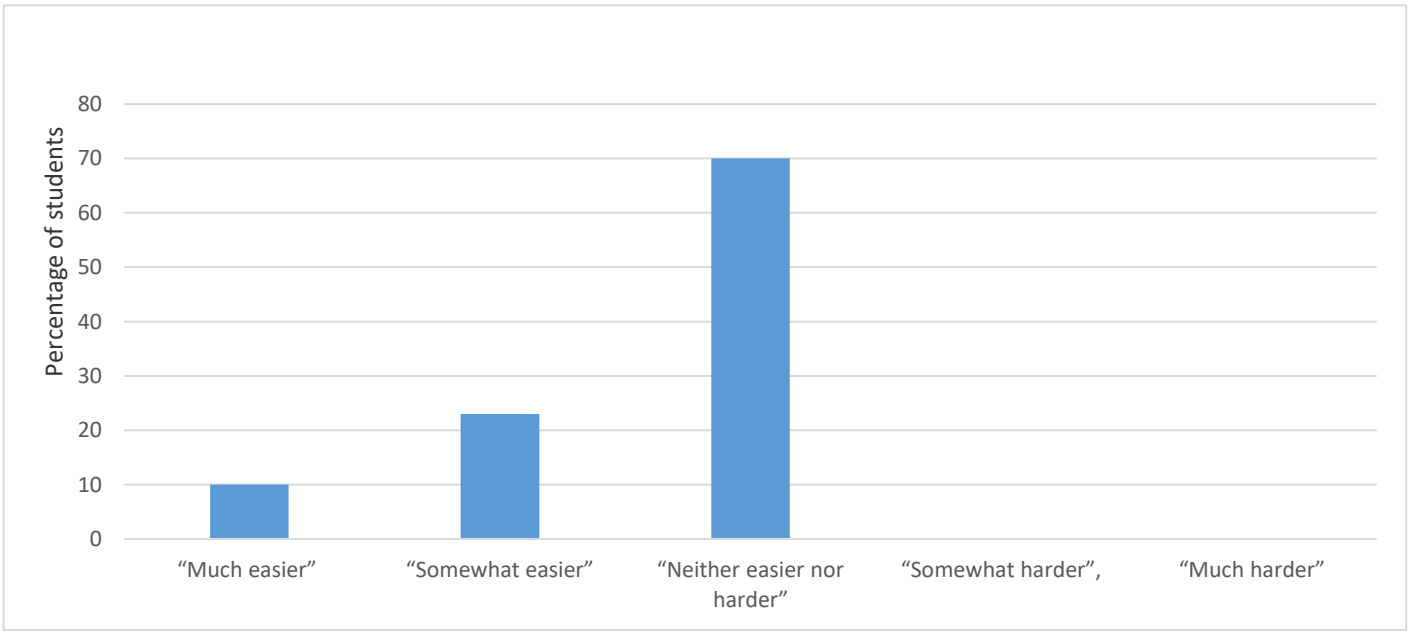

Figure 5. Students' Perception of How Noise Level of 38dBA Can Affect Their Schoolwork

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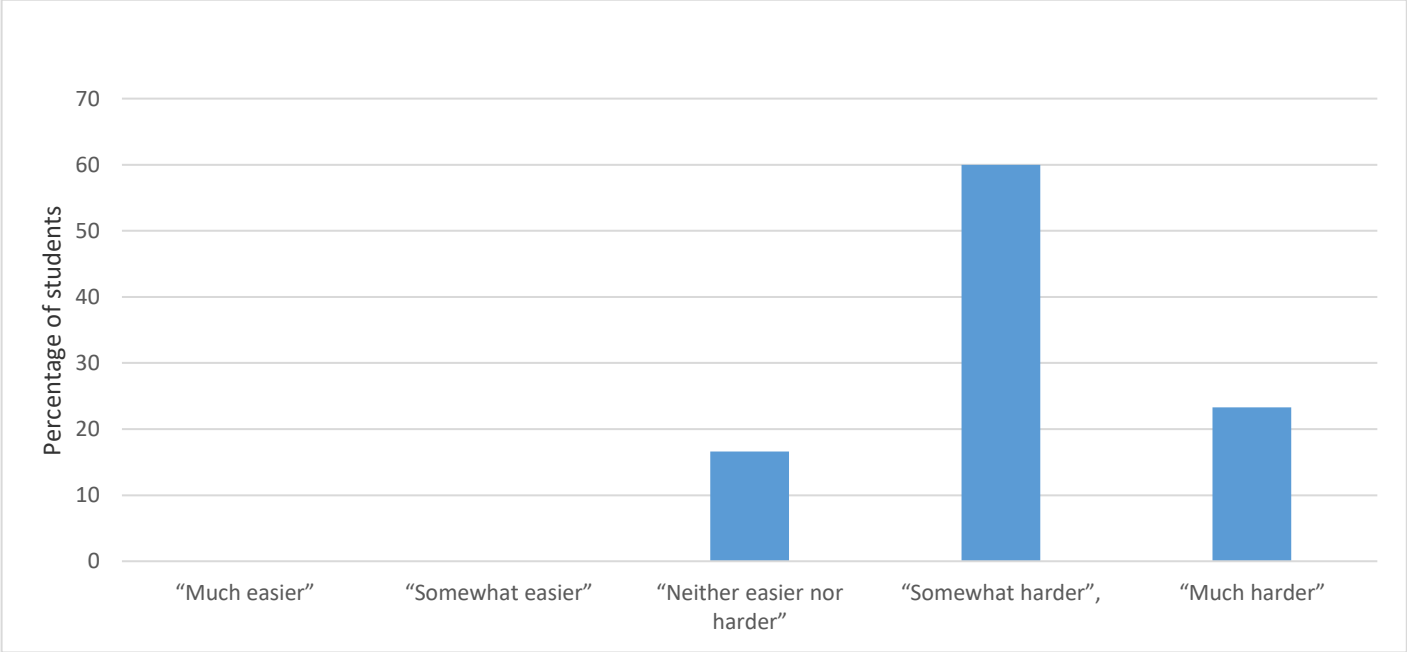

Figure 6. Students' Perception of How Noise Level of 75dBA Can Affect Their Schoolwork

DISCUSSION

The present study examined the effect of exposure to noise on performance and emotional wellbeing of students in a private secondary school at Kaduna, Nigeria.The results from this study show that academic task in classrooms with noise level above 75 dBA significantly affected the performance of students in mathematics tasks. In the English language task, the results suggest that there was no signficant effect of noise on the performance of the students. It should be noted that the performance in the English language task was lower at 75 dBA compared to 38 dBA.

One reason that may have influnced the effect of noise on mathematics based task reported in this study, was that the students may have found the mathematics task more complex than the English language based task. This result supports earlier study by Landstrom and colleagues (Landstrom et al., 1993). They reported that noise effect on the performance of task can be dependent on the complexity (difficulty) of the task (Landstrom et al., 1993). The signficant effect of noise on the performance of mathemathics based task reported from the results in this study was plausible because the values of some environmental conditions in the classrooms for this study were within the recommended standards (WHO, 1999). Specifically, subsection 3.1 of the WHO reports the values of some of the indoor environmental conditions found in the classroom during the field experiments carried out in this study.Taken together, the findings concerning signficant effects of noise on mathemathics task resonates the findings from previous research (Dockrell &Shield, 2006; Connolly et al., 2016).

As regards annoyance effect of noise, results from this study shows that the students were significantly annoyed at noise level of 75 dBA in comparison to 38dBA. The significant effect of annoyance corresponds to "very annoying" on the visual analogue scale in Figure 1. This result suggests that the students in Exp II were very annoyed when they performed tasks at 75 dBA. Ssimilarly, this result corresponds to the findings from the study of Lundquist et al. (2000). Perhaps, annoyance could have contributed to why the students in Exp II performed significantly less from the result of the mathemathics earlier reported in this study.

Overall, the result concerning annoyance suggests that if students are not emotionally happy in classroom due to an environmental stressor, they are likely not to perform well. By extension, the significant effect of annoyance reported from the results in this study has the potential of affecting the emotional wellbeing of students.

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Also, the results from this study suggested that students could find it more difficult to perform academic tasks at relatively high noise levels of about 75 dBA. The implication is that higher noise levels can potentially increase task difficulty for students in school environments.

CONCLUSIONS

In view of the negative effects of high noise level reported from the results of this study, designers of schools and educational policy makers should consider acoustical qualities of schools and create learning environments that promote the perfomance and wellbeing of students. Although, this was not part of the findings from the present study, it strongly implied that materials for construction and renovation of learning environments should prioritise acoustic design and sound insulation principles to reduce impact sounds from both internal and external sources.

Future research can investigate the effect of noise on performance tasks with teachers to see how results may vary or differ. While the present study used relatively small sample in comparison to the number of schools in different regions of the country, future research may focus on gathering data from many samples longitudinally across different regions in Nigeria.

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Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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