Longitudinal Effects of Exposure to Chronic Aircraft Noise on School Children's Activities

Joseph Seabi, Kate Cockcroft, Paul Goldschagg

Abstract— The aim of this study was to determine whether chronic exposure to aircraft noise impacts negatively on school children's activities and to explore how they cope with the noise exposure. Given the lack of longitudinal studies investigating long-term effects of exposure to aircraft noise on children's activities and coping, this study sought to address this gap. A cohort of 732 children in South Africa with a mean age of 11.1 (range = 8-14) participated at baseline measurements in Wave 1 (2009), and 649 (mean age = 12.3; range = 9-15) and 174 (mean age = 13.3; range = 10-16) children were reassessed after the relocation of the airport in Wave 2 (2010) and Wave 3 (2011), respectively. The results revealed that the children who were exposed to aircraft noise were significantly disturbed by aircraft noise in all the waves (2009-2011) than those who attended schools in relatively quieter environments. It was also found that the children who were exposed to aircraft noise continued to use more coping strategies (e.g. covering of ears, tuning out, and waiting for noise to finish) than their counterparts despite the relocation of the airport, thereby suggesting that aircraft noise exposure has long term effects on children's performance.

Index Terms— activities, aircraft noise, coping strategies, epidemiology, children, South Africa.

1 Introduction

A sound that interferes with people's normal activities such as conversation and activities is commonly regarded as noise. Noise, defined as unwanted sounds, is a major problem in schools nowadays as it undermines the conditions required for conducive learning and teaching [1]. There is a growing body of research in developed countries, which shows negative associations between aircraft or road traffic noise and children's reading comprehension [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], 12], memory [4], [7], [9], [10], [11], [12], [13], attention [6], [9], [14], motivation [9], [12], blood pressure [9], [15], annoyance/quality of life [9], [11], [16], and stress [6], [9]. Despite this body of research, little is known about the associations of aircraft noise exposure with children's performance in developing countries, particularly within the African contexts. Furthermore, most of the studies in this area are based on cross-sectional and laboratory studies, with the exception of the Los Angeles Airport Study and the Munich Airport Study [10], [17], [18], [19]. Laboratory studies lack ecological validity, whereas studies of real-life exposure to noise are more likely to reveal whether long-term noise exposure has any effect on learning activities and how children cope with noise exposure. Although less economical, large scale prospective studies may provide much higher degrees of control over types and quality of the data collected, and with that, better statistical control over potential confounders [20].

The relocation of the Durban International Airport in South Africa to La Mercy, which is approximately 35 kilometers north of the city centre of Durban, provided us with an unprecedented opportunity to conduct a prospective longitudinal study of the effects of exposure to aircraft noise on children's activities. To the best knowledge of the authors, this is one of the first largest longitudinal studies of nonauditory effects of aircraft noise on children to be undertaken within the African continent. Lazarus [21] argues that long-term research of this kind is needed for the study of coping and stress as factors in health take a long time to develop and emerge. Therefore, relocation of the airport provided a rare opportunity to determine not only whether aircraft noise exposure interferes with children's activities, but also if such interferences are found, whether they persist despite relocation of the airport, become worse, or whether children are able to adapt and catch-up with their quieter counterparts group.

2 Coping with Noise

In order to be able to develop interventions that address exposure to noise, it is essential to understand how children cope with noise-exposure to reduce its impact on them. People implement various coping strategies as a way to cope or deal with the high noise levels, failure of which

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may result in psychological distress. There are direct coping strategies such as turning off of the noise sources and negotiating with the people generating the noise, as well as indirect strategies which entails cognitive control [22]. The direct coping strategies are often difficult to carry out in most situations as they are commonly beyond an individual's control, thereby leaving one with indirect coping strategy to reduce annoyance to noise [23], [24]. Miedema developed a model that states four main interferences (i.e. sound masking, attention route, arousal route affective/emotional route) caused by environmental noise, which may or may not be followed by acute or chronic stress responses [25]. This model illustrates how an environmental noise disturbance as a stressor, can interfere with behavior (concentration, communication) and desired state (relaxation and sleet). It is the ability to cope with the stressor that is essential for an individual's health and well-being. According to the WHO Guidelines, young children, elderly people and those who are ill, may be less able to cope with the effects of exposure to noise due to their vulnerability and as a result, they are likely to experience harmful effects [26].

One qualitative study explored children's perceptions of noise and how they coped with it [24]. From a sample of 36, children reported that their daily activities (homework, school work, playing) were affected by high levels of aircraft noise than those from quieter environments. Depending on the amount of control the children had on the noise sources, the children implemented different coping strategies. Although they felt that they could close the windows or tell their neighbors to be quiet, they were not in control over noise generated outside their homes such as aircrafts and busy roads. In order to cope with the sources of noise, the majority of these children covered their ears, wore headphones or played music, and these methods were followed by thinking about something else and telling the person to be quiet. It was also found that different sources of noise were associated with different emotions, whereby the negative emotions (i.e. annoy, sad) were largely linked to traffic and industrial noise; meanwhile positive emotions (i.e. happy) involved natural sounds such as the wind, and household noises (i.e. fans, television). Two-third of the children wished for their environments to be quieter, versus a third of them that thought noise was acceptable as it was. Given these findings, it is essential to investigate through longitudinal analyses whether exposure to noise interferes with children's activities; if so, whether such interferences persist despite the cessation of environmental stressor; and whether there are significant differences in coping strategies among children in the noise-exposed and quieter groups in the South African context.

2.1 Research Questions

The current study aimed to investigate the longitudinal effects of aircraft noise exposure by tracking children who were exposed to chronic aircraft noise over three-time periods. This study was guided by the following questions:

1) Is there a statistically significant difference between children in the noise and quiet groups in terms of disturbances to activities at school and home before and after relocation of the airport?
2) Is there a statistically significant difference between children in the noise and quiet groups on how they cope with noise exposure before and after relocation of the airport?

3 METHODS

3.1 Participants

This paper is based on a cohort of 732 children with a mean age of 11.1 (range = 8-14) who participated at baseline measurements in Wave 1 (2009). A cohort of 649 (mean age = 12.3; range = 9-15) and 174 (mean age = 13.3; range = 10-16) children were reassessed after the relocation of the airport in Wave 2 (2010) and Wave 3 (2011), respectively. There was a high attrition of participants in Wave 3 because permission to follow-up learners in Grade 8 (i.e. new schools) was not granted by some school principals, as well as the bad weather during the assessment day, which resulted in many learners not coming to school. Research indicates that although prospective longitudinal studies are one of the strongest research methodologies for studying aetiological mechanisms [27], they are vulnerable to participant attrition [28]. Table 1 illustrates the socio-demographics of the sample.

4. INSTRUMENTS

4.1. Biographical Questionnaire

Information pertaining to participants' gender, age, and languages was obtained from biographical questionnaires completed by the participants. The child questionnaire was administered in print form and completed before the assessment. Socio-economic status was assessed by the percentage of children eligible for free meals at school, since research indicates that there is a "significant correlation between the free school meal ratio and a range of census indicators representative of socio-economic status [29, p.21]. A criterion for a child to be eligible for a free school meal is that the child's caregiver should be receiving a government social grant.

4.2. Disturbance at activities

The children were instructed to rate on a four-point scale (1=never to 4= always) whether they find aircraft noise interfering with their playing outdoors, listening to the teacher, working quietly by oneself, and working in a group.

4.3. Dealing with noise

The children responded on a four-point rating scale (1=never to 4=always) on how they cope with noise at home and school. For instance, the items included dealing with noise by covering one's ears, carrying on with one's work, switching off (tuning-out), and waiting for noise to finish.

4.4. Noise measurements

The instrument used to measure noise was a SVAN 955 Type 1 sound level meter. A Rion NC74 acoustic calibrator was used to check the instrument calibration before and after the measurements was performed. Noise measurements were taken during the testing period (8 a.m. to 10 a.m.) outside the classrooms in order measure aircraft noise levels. The baseline Leq noise measurements for the High Noise groups at the noise exposed schools near the flight path (Wave 1) varied from 63.5 to 69.9 Leq. Maximum noise levels varied from 89.8 to 96.5dBA Lamax. In the case of the Low Noise groups at schools in relatively quieter areas, noise measurements during Wave 1 testing yielded results of 54.4 to 55.3 Leq and 73.2-74.3 Lamax. Noise measurements during Waves 2 and 3 when aircraft were gone produced results at the formerly noise exposed schools of 55.2 Leq and maximum noise levels of 60.8 to 71.2 Lamax. Levels at the quieter schools were averages of 50.5 to 57.9 Leq and 60.6 to 70.5. No measurements were conducted at the children's homes as schools are located within a walking distance.

5. PROCEDURES

Written permission was obtained from the education authorities and from the parents to allow their children to participate in the study. The children were informed of the limits of confidentiality, as well as the voluntary nature of their participation. Informed assent from the children was thus obtained. The measurements were group-administered in the classrooms in the morning between 8am and 10am. The pre-test measures were administered in Wave 1 (2009) before relocation of the airport and post-test measurements took place in Wave 2 (2010) and in Wave 3 (2011). A detailed procedure is presented elsewhere [30].

5 STATISTICAL ANALYSIS

Statistical Analysis System (SAS) version 9.2 was utilised to conduct statistical analyses. In line with the previous study [10, p.470] "all *F* tests with repeated measures of wave were treated as multivariate analyses of variance, MANOVAs, rather than univariate analyses of variance, ANOVAs. These MANOVAs yield higher *p* values and thus are more conservative, than the corresponding univariate epsilon-corrected Greenhouse-Geisser ANOVAs." Effect estimates were presented as odds ratios (ORs) with 95% confidence intervals (CIs) for socio-demographic characteristics.

7 RESULTS

7.1 Disturbance at school and home activities

Table 2 indicates that the noise-exposed children were significantly disturbed by aircraft noise at school than those in the quiet group in Wave 1 ($F_{1, 732}$ = 139.28, P=0.00), Wave 2 ($F_{1, 649}$ = 17.21, P=0.00) and Wave 3 ($F_{1, 174}$ = 5.69, P=0.01). In terms of disturbances at home, a statistically significant difference was found between the groups only in Wave 1 ($F_{1, 732}$ = 25.56, P=0.00). As illustrated in Fig. 1, there were significant interactions ($F_{2, 174}$ = 3.54, P=0.03) similar to trends of the main effects, where the mean scores of the noisy group were substantially higher than that of the quieter group in Wave 1, Wave 2 and Wave 3 in terms of disturbances on activities at school. Fig. 2 provides graphical representation of significant interaction effects of Group X Wave ($F_{2, 174}$ = 2.94, P=0.05) in terms of disturbances on activities at home. Of noteworthy is that although children in the noisy group were substantially disturbed by aircraft noise at home before the relocation of the airport (Wave 1), these effects diminished at Wave 2 and Wave 3.

7.2 Coping with noise at school and home

Table 3 indicates that the noise-exposed children significantly implemented more coping strategies (e.g. covering of ears, tuning out, and waiting for noise to finish) at school than those in the quieter group in Wave 1 ($F_{1, 732}$ = 43.07, P=0.00) and Wave 2 ($F_{1, 649}$ = 5.63, P=0.01). There was however no significant difference between the groups in Wave 3 ($F_{1, 174}$ = 0.87, P=0.35). In terms of exposure to noise at home, children in the noisy group also implemented more coping strategies than their counterparts in Wave 1 ($F_{1, 732}$ = 6.96, P=0.00). There was no significant difference between the groups regarding their coping strategies in Wave 2 ($F_{1, 649}$ = 0.13, P=0.71) and Wave 3 ($F_{1, 174}$ = 0.37, P=0.54). Fig. 3 and 4 present visual representation of the results.

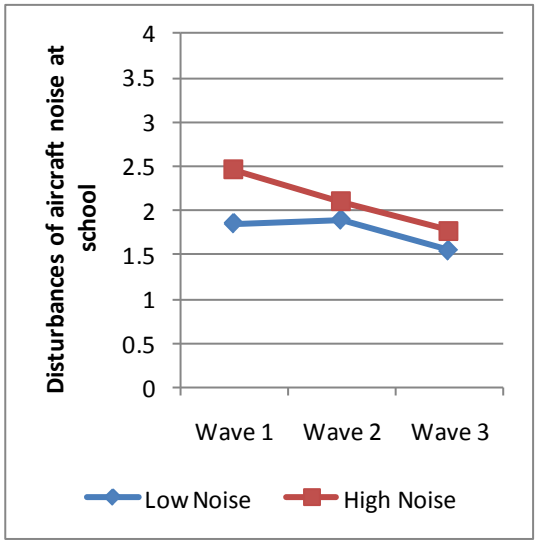

Fig. 1 Disturbances of aircraft noise at school

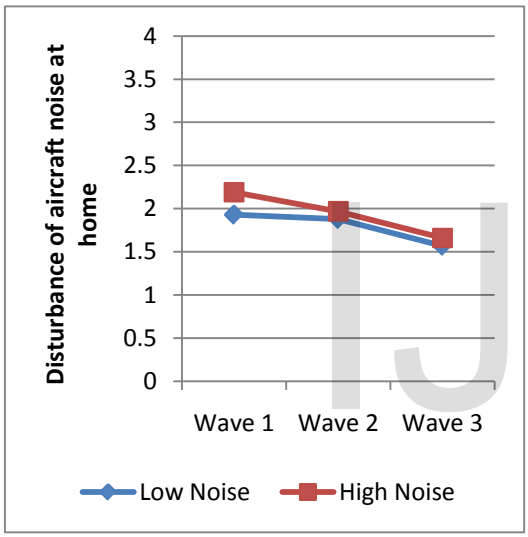

Fig. 2 Disturbance of aircraft noise at home

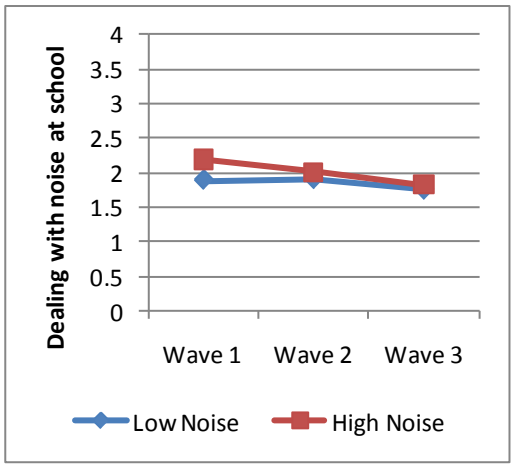

Fig. 3 Coping with noise at school

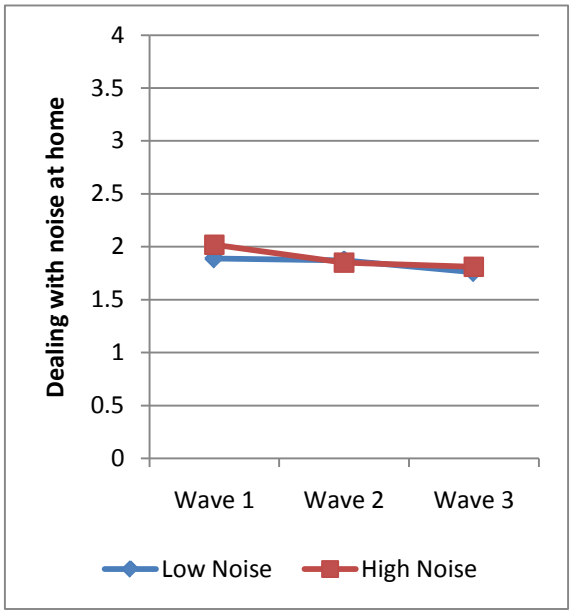

Fig. 4 Coping with noise at home

8 DISCUSSION

There were two main findings in this study. First, children's activities were substantially disturbed at school throughout all the waves within the noise-exposed group than those in relatively quieter area. Second, the children who were exposed to aircraft noise continued to use more coping strategies (e.g. covering of ears, tuning out, and waiting for noise to finish) than their counterparts despite the relocation of the airport. Taken together, these findings provide evidence that aircraft noise exposure adversely affects children's school activities and that these effects have a lasting impact on children's functioning.

8.1 Disturbances at activities and coping strategies

The results in the present study demonstrated that school activities of the noise-exposed children were significantly disturbed than those of children from quieter environment throughout all the waves. These findings are consistent with the literature which reveals that children who live within the vicinity of the airport feel that their performance on activities is affected by exposure to noise [7]. Haines and Stansfeld found that children exposed to aircraft noise reported interferences with their classroom activities such as working and thinking [31]. In another study, it was found that children attending school in noisy area reported that the train noise bothered them, and influenced their ongoing activity [32]. The World Health Organization thus recommends that the permissible level of noise in school environments should not exceed 35 dB [26]. However, many children do not have access to ideal or calm learning environments, particularly in less developed countries [31] such as South Africa, where some children in remote rural areas attend schools under trees. In order for children to perform at their optimal levels and to succeed scholastically, they should be at an environment that is conducive to teaching and learning.

Of significant interest is that children in the noise-exposed group reported high levels of disturbances to their activities in all the waves, despite relocation of the airport after Wave 1. In addition, these children utilized more coping strategies at school at Wave 1 and Wave 2 than those in the quieter group. It thus seems that the effects of chronic exposure to aircraft noise are long term, and these results corroborate previous studies. An earlier study found that reducing the noise inside a school by 16 dB(A) had little effect on children's performance [15]. It was also revealed that even when the sources of noise were removed, as in the closure of the airport, it took several years for adverse effects of exposure to noise to cease [8].

Although statistically significant differences were found between the groups before and after the relocation of the airport, there was a declining trend particularly within the noise-exposed group as illustrated by Fig. 1 to 4. These findings can be explained by the partial retention of behavioral coping strategies [33], which suggests that when people experience a change in noise exposure, they change some of their coping strategies such as closing windows, but they partially retain such strategies after the change, thus resulting in excess effect [34].

The implications of these findings are that chronic aircraft noise-exposure has a lasting impact on children's learning and development. These effects appear not to be reversible. It is therefore crucial that policy makers and airport officials ensure that children's school environments are conducive to their learning and development, that environmental hazards such as noise pollution are avoided and/or eliminated.

8.2. Strengths and limitations

To best knowledge of the authors, this longitudinal field study is the first largest study to date to examine the effects of aircraft noise exposure on children's activities and how they cope with noise exposure. A major limitation of the study is that, while the analyses are based on the 2009-2011 longitudinal data, the 2011 cohort was very small because significant proportions of the participants were lost due to attrition. Another limitation relates to the exclusive focus on aircraft noise impacts and not on the other sources of noise (such as road traffic, construction, railway noise etc.), which may have compounded the results.

9 CONCLUSION

The results of this longitudinal study provide stronger evidence than previous studies that aircraft noise exposure impacts negatively on the school activities of the children, which affects how they cope with it. The fact that the noise-exposed children's activities remained disturbed and these children continued to use more coping strategies than their counterparts, despite the relocation of the airport, provides evidence that chronic exposure to aircraft noise has a lasting impact on children's learning activities. Therefore children should be protected from such environmental hazards.

Table 1. The socio-demographic characteristics of the high noise and low noise groups

	Wave 1				Wave 2				Wave 3			
	Low Noise	High Noise	OR	(95% CI)	Low Noise	High Noise	OR	(95% CI)	Low Noise	High Noise	OR	(95% CI)
Boys	49%	51%	0.92	0.69-1.23	50%	50%	1	0.73-1.36	49%	54%	0.8	0.44-1.48
English	55%	59%	0.83	0.62-1.12	58%	62%	0.85	0.61-1.18	67%	53%	1.8	0.96-3.41
Deprived	30%	40%	0.62	0.46-0.85	31%	39%	0.70	0.50-0.99	43%	51%	0.73	0.39-1.35

Table 2. Disturbance at school and home activities

Wave 1				Wave 2				Wave 3			
Low Noise Mean	High Noise Mean	Difference Score (95% CI)	DF, N, F, *P*- value	Low Noise Mean	High Noise Mean	Difference Score (95% CI)	DF, N, F *P-value*	Low Noise Mean	High Noise Mean	Difference Score (95% CI)	DF, N, F, *P*- value
At School											
1.85	2.46	-0.60 (-0.70-0.50)	(1, 732) F=139.28 P=0.00*	1.89	2.10	-0.21 (-0.31-0.11)	(1, 649) F=17.21 P=0.00*	1.55	1.77	-0.21 (-0.39-0.03)	(1, 174) F=5.69 P=0.01*
At Home											
1.93	2.19	-0.26 (-0.36-0.16)	(1, 732) F=25.56 P=0.00*	1.88	1.97	-0.08 (-0.19-0.01)	(1, 649) F=2.62 P=0.10	1.57	1.66	-0.08 (-0.27-0.09)	(1, 174) F=0.88 P=0.34

Disturbed by aircraft noise;
* p < .05

Table 3. Coping with noise at school and home

	Wave 1				**Wave 2**				**Wave 3**			
	Low Noise Mean	High Noise Mean	Difference Score (95% CI)	DF, N, F, *P*- value	Low Noise Mean	High Noise Mean	Difference Score (95% CI)	DF, N, F *P-value*	Low Noise Mean	High Noise Mean	Difference Score (95% CI)	DF, N, F, *P*- value
<u>At School</u>												
Item 1	1.89	2.19	-0.29 (-0.38-0.20)	(1, 732) F=43.07 P=0.00*	1.90	2.01	-0.10 (-0.19-0.01)	(1, 649) F=5.63 P=0.01*	1.75	1.83	-0.08 (-0.25-0.09)	(1, 174) F=0.87 P=0.35
Item 2	2.65	2.77	-0.11 (-0.24-0.01)	(1, 732) F=3.10 P=0.07	2.59	2.49	-0.09 (-0.03-0.23)	(1, 649) F=2.08 P=0.14	2.41	2.64	-0.23 (-0.51-0.04)	(1, 174) F=2.65 P=0.10
<u>At Home</u>												
Item 1	1.89	2.02	**-**0.12 (-0.21-0.03)	(1, 732) F=6.96 P=0.00*	1.87	1.85	0.01 (-0.07-0.11)	(1, 649) F=0.13 P=0.71	1.76	1.81	0.05 (-0.24-0.12)	(1, 174) F=0.37 P=0.54
Item 2	2.39	2.44	-0.05 (-0.18-0.07)	(1, 732) F=0.43 P=2.29	2.29	2.16	0.13 (-0.00-0.27)	(1, 649) F=3.56 P=0.05*	2.14	2.37	-0.22 (-0.50-0.05)	(1, 174) F=2.52 P=0.11

KEY: 1= Coping strategies used (covering of ears, tuning out, and waiting for noise to finish); 2=Wish for quietness;
* p < .05

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