# The impacts of environmental noise on the academic achievements of secondary school students in Greater London

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**Abstract**

Previous studies on the detrimental impact of chronic external noise upon the academic performance of school children were normally based on sampled school sites, and the results were often limited to a specific range of areas. The aim of this paper is to investigate the relationships between environmental noise levels of secondary schools in Greater London and a set of academic achievement factors, and also, to determine the noise exposure of secondary schools. Four academic achievement indicators were considered and five noise indicators were obtained after processing noise map data. It has been shown that the environmental noise levels of secondary schools in Greater London have almost no significant relationships with those academic achievement indicators. As expected, the secondary schools in Inner London are noisier than those in Outer London. The average difference is calculated as 2dBA.

**Keywords:**

Secondary school, noise map, academic achievement, London

## 1. Introduction

Noise pollution is a major environmental problem, and some estimated 10 millions of people in Europe are exposed to the excessive traffic noise, which may cause stress, illness and even fatal impact. At a conservative estimate, the social costs of traffic noise amount to 0.4% of total GDP [1]. In the UK, according to the national noise survey, people indicated that the road traffic noise around their home had got worse over the last five years, and the majority of the UK population were affected by the noise levels above those suggested by the WHO Guidelines for Community Noise [2].

There have been some studies on the detrimental influence of chronic external noise upon the academic performance and attainments of school children. A number of findings have indicated that chronic noise exposure would impair concentration, general cognitive functioning, and particularly reading skills [3-9]. However, previous evidence was normally based on subjective or field surveys with sampled school sites, and the results were often limited to a restricted range of areas and in particular, the research on the secondary schools has been limited. A key study relating to this research was conducted by Shield and Dockrell [3], to examine the impact of external and internal noise on the academic attainments of London primary school children, although it only considered a number of schools situated in 3 London boroughs. It was found that external noise has a significant negative impact upon performance, the effect being greater for the older children.

Recently large-scale urban strategic noise mapping has become an essential requirement, particularly in European countries [10-12], and corresponding techniques have been widely adopted in practice for the establishment of noise strategies and planning policies [13-16]. A noise map, typically in a form of interpolated iso-contours, is a way of presenting the geographical distribution of noise exposure, either in terms of calculated or measured levels [17]. Whilst there have been varied attempts to improve the accuracy [18-20], computing-based noise mapping techniques are certainly useful for relative comparisons, especially for large scale areas [21].

The socio-acoustic research approach has been widely applied in similar research questions, for instance the relationship between human reactions to noise and non-acoustic variables, like income and occupational status [17,22-27].

The aim of this study is to investigate the relationships between environmental noise levels of secondary schools from noise mapping calculations and a set of academic achievement factors, as well as to determine the noise exposure of secondary schools. For that the Greater London is considered as a case study city.

## 2. Methodology

### *2.1 Academic achievement indicators*

Every year the Department of Children, Schools and Families (DCSF) publishes the Achievement and Attainment Tables for all the secondary schools in England. These tables give information on the overall performance of each school, which is helpful for parents when choosing secondary schools for their children. As previous research suggests that environmental noise has a negative impact upon pupils' performance [3, 7, 9], four major achievement indicators were considered for this study, including the average total point score per pupil of Key Stage 4, CVA score, overall and persistent absence.

A Key Stage is a part of the British state educational system for students at various ages. Pupils aged 14 to 16 years old normally enrol in Key Stage 4 and at the end of this stage there is a range of exams typically of the GCSE level (General Certificate of Secondary Education). The average total point score provides a fuller picture of the achievements of pupils of all abilities at Key Stage 4.

Contextual Value Added (CVA) score measures the progress made by pupils from the end of Key Stage 2 (KS2) to the end of Key Stage 4 (KS4), using their test and exam results. CVA takes into account the varying starting point of each pupil's KS2 test results, therefore provides a fairer indication of a school's overall effectiveness [28]. The overall absence is the percentage of possible half-days recorded under any combination of the authorised and unauthorised absences for schools which do not report absence by reason, while persistent absence is the percentage of pupil enrolments equalling or

exceeding the threshold number of half-day absences over the Autumn and Spring terms combined [28].

Due to the lack of appropriate income and occupational data, this study did not take into account the effect of social variables on the correlation results.

*2.2 Selection of secondary schools*

As the capital of both England and the UK, Greater London covers 1572 km² and had a most recent (mid-2007) estimated population of 7.56 million accounting for 14% of the England and Wales total [29]. Noise levels in Greater London were measured to be significantly higher than those over the whole of England and Wales. Road traffic noise was heard and reported as causes of annoyance by a greater proportion of respondents in Greater London than nationally [30].

More than 500 secondary schools are listed in Greater London in the DCSF Achievement and Attainment Table. Regarding the initial selection, the schools without applicable academic achievement factors were automatically excluded from the selection. There are two large and busy airports in Greater London, namely London Heathrow Airport and London City Airport. The impact of aircraft noise on the school children have been studied by a number of researchers [9, 31, 32], and in this study the schools in the areas where aircrafts are dominant noise sources were excluded due to their special

features. According to the official airport noise maps [33], the schools located within 60dB zone were deleted from the above list.

Based on random number generation, 96 secondary schools in Greater London were identified and verified in accordance with relevant noise maps. Data in both academic achievement and noise aspects were then obtained from corresponding databases.

The administrative area of Greater London is generally divided into Inner and Outer London. Inner London forms the interior part of Greater London with a land area of 319 $km^2$ and the population is 3 million. Occupying 1253 $km^2$ for 4.57 million residents, outer London forms a ring around Inner London [29]. Inner London is considered as one of the richest areas in Europe.

*2.3 Processing of noise map data*

The original data calculated for the noise levels of secondary schools in Greater London were obtained from an open database called London Noise Maps, produced and hosted by Atkins from 2004 to 2008 on behalf of DEFRA [14]. It considers road traffic as the predominant noise source in London. The maps represent the average noise levels at a height of 4m above the local ground level, according to the EU regulations [10-12]. It is assumed that the roads are dry but the wind is adverse, namely blowing from the road to the receiving position. The published colour noise maps were processed to obtain a series of digital numbers for the following analysis. The average noise levels of London Noise Maps are expressed in $L_{den}$, which is a logarithmic composite

of the day, evening and night levels [21]. After being smoothed for display, each pixel in the noise map indicates a 1m×1m square in reality.

Every house and business in the UK has been given a postal address to sort and deliver mail quickly and accurately. The postcodes have been widely adopted for many other purposes such as the important geographic references to pinpoint the UK locations automatically on a map. The approximate boundary of a sampled school was firstly approached from the noise map database in accordance with its unique postcode. As the initially obtained noise maps may contain other unwanted buildings or areas surrounding the schools but are actually not a part of the selected schools, essential boundary information was double checked through GoogleMap and StreetMap to ensure every building of the studied school was not excluded.

A MATLAB program was developed for the further processing of the identified noise map data. Figure 1a illustrates a typical noise map of a secondary school in Greater London, where each colour represents a 5dBA scale, which is the highest available resolution from the published noise maps. Since the noise levels range from 35 to 85dBA, this resolution is acceptable for this study. Firstly a noise map is loaded into MATLAB program, and all the colours of that map will be automatically transformed to corresponding noise values in a 2D grid system. Two sets of matrix are subsequently generated, as illustrated in Figure 1b and 1c. In Matrix A (see Figure 1b), 0 represents the location of building blocks and other values refer to the actual noise levels in dBA at grid points where applicable. Based on Matrix A, Matrix B (see Figure

1c) is produced to demonstrate the noise environment around the school buildings, where only the noise levels at the grid points indicating the 1m external locations outside the facades of selected school buildings are retained, while all the other values are assigned to 0. It is noted that Figure 1b and 1c correspond to the area highlighted with dotted lines in Figure 1a.

The next step was to decide the appropriate noise level indicators for a specific school, after identifying the relevant noise values for all the buildings of a secondary school. Five noise indicators were introduced to this research, including the average spatial noise level $L_{s\text{-}ave}$ (dBA), maximum spatial noise level $L_{s\text{-}max}$ (dBA), minimum spatial noise level $L_{s\text{-}min}$ (dBA), intrusive spatial noise level $L_{s\text{-}10}$ (dBA) and background spatial noise level $L_{s\text{-}90}$ (dBA), respectively. It is noted that $L_n$ generally represents the level of noise exceeded for n% of the specified measurement period, whereas in this study they were to represent spatial rather than temporal distribution. In other words, if *N* noise levels are obtained for a school from Matrix B and they are sorted in an descending order, then $L_n$ is the (*100n/N*)th noise levels in the order.

*2.4 Data analysis*

The software SPSS was used for the statistical analysis. One-Sample Kolmogorov-Smirnov normality tests were firstly conducted for both academic and noise indicators. Normality hypothesis is to be rejected if 2-tailed asymptotic significance value *p* is less than 0.05. The averaged Key Stage 4

score ($p$=0.226), overall absence ($p$=0.574), persistent absence ($p$=0.291), as well as $L_{s\text{-}ave}$ ($p$=0.973) followed the assumption of normality, whereas the other indicators were not normally distributed ($p$<0.05).

To investigate how the noise levels and academic achievement are related, the Pearson correlation and Spearman correlation were performed. Pearson correlation is preferred in measuring the degree of linear relationship between normally distributed variables, while Spearman correlation does not rely on any assumptions about variables' distribution as a non-parametric test [34]. Therefore the Pearson correlation was performed only in the case of normal distributions for both noise and academic indicators. The Independent-Samples t test was applied to compare the environmental noise levels of secondary schools in Inner and Outer London. It is noted that in all the tables in this paper, ** indicates $p$<0.01 and * indicates $p$<0.05 in terms of correlation significance.

## 3. Results and discussion

### *3.1 Environmental noise levels of secondary schools in Inner and Outer London*

Table 1 demonstrates the comparison of five noise indicators, namely the average, maximum, minimum, spatial background and intrusive noise levels between secondary schools located in Inner and Outer London. As expected, the latter is generally lower than the former, although the mean differences

are small in magnitude ranging from 0.6 to 3.6dBA, and not statistically significant for most noise indicators, except the intrusive noise level $L_{s-10}$ ($p$<0.05). $L_{s-10}$ is normally related to the direct sounds towards the buildings. Previous findings also suggested that the noise climate of Inner London is different from that of Outer London in terms of noise levels, noises heard and attitudes to noise [2]. It is also noticed that $L_{s-max}$ in Table 1 is relatively low compared to the conventional temporal indicator of $L_{max}$, which is because $L_{s-max}$ only indicates the spatial maximum value of average external noise levels outside the selected school buildings.

The Building Research Establishment (BRE) completed a national noise incidence study in 2001 [2] and a specific London noise survey in 2004 [35]. The actual noise level, based on the site measurements covering seven Outer London boroughs where the population is greater and four Inner London boroughs, is relatively higher than that of the average noise level of London secondary schools, with a considerable difference of approximate 7dBA. The large number of internal space and facades within the school premises is likely to be the reason.

*3.2 Correlations between noise levels and academic achievements*

In Table 2 the correlations between five environmental noise indicators of secondary schools and four academic achievement indicators are shown. It is shown that all the environmental noise levels have no significant correlations with the academic achievement indicators of the sampled schools, and the

correlation coefficients are very low. This suggests that external noise levels may not be a good indicator of internal and overall noise levels, for which previous studies have shown a significant impact on academic achievement [3]. Clearly the airborne sound insulation of building envelopes could play an important role [36]. There are also differences in terms of noise types, education stage of schools and external activities.

There are markedly variations between secondary school sites within Greater London, in terms of environmental noise levels and distance to the main roads. As shown in Table 3, the difference between the maximum and minimum noise levels of selected schools is more than 20dBA. Therefore, all the schools were sorted by the noise levels in a descending order. The first 25 schools with greater levels were then selected as a sub-group, called road-side school group for the sake of convenience, representing those more influenced by the direct sound of traffic noise and more likely to be close to the main roads. For these road-side schools, all the indicators were normally distributed, except the noise indicator $L_{s\text{-}min}$ and $L_{s\text{-}90}$.

Further correlations between the five environmental noise indicators of those 25 secondary schools and the four academic achievement indicators are analysed, as shown in Table 4. It can be seen that the only significant correlation was found between the intrusive environment noise and persistent absence ($p$<0.05). It is interesting to note that past studies have revealed that both socio-economic issues and classroom environment quality are related to student absence [37-39]. It is possible that similar to the effect of classroom

CO2 concentrations on attendance rate [39], excessive external noise level might also be associated with student absence.

Moreover, the correlation coefficients of this group are generally greater than those of other schools. However, the overall correlation coefficients are still not high, as a measure of how the noise exposures are linearly related to students' academic performance.

## 4. Conclusions

Through the use of noise map database, the analysis shows that the secondary schools in Inner London are noisier than those in Outer London, with an average difference of 2dBA. It has been shown that the environmental noise levels of secondary schools in Greater London have almost no significant relationships with the academic achievement indicators.

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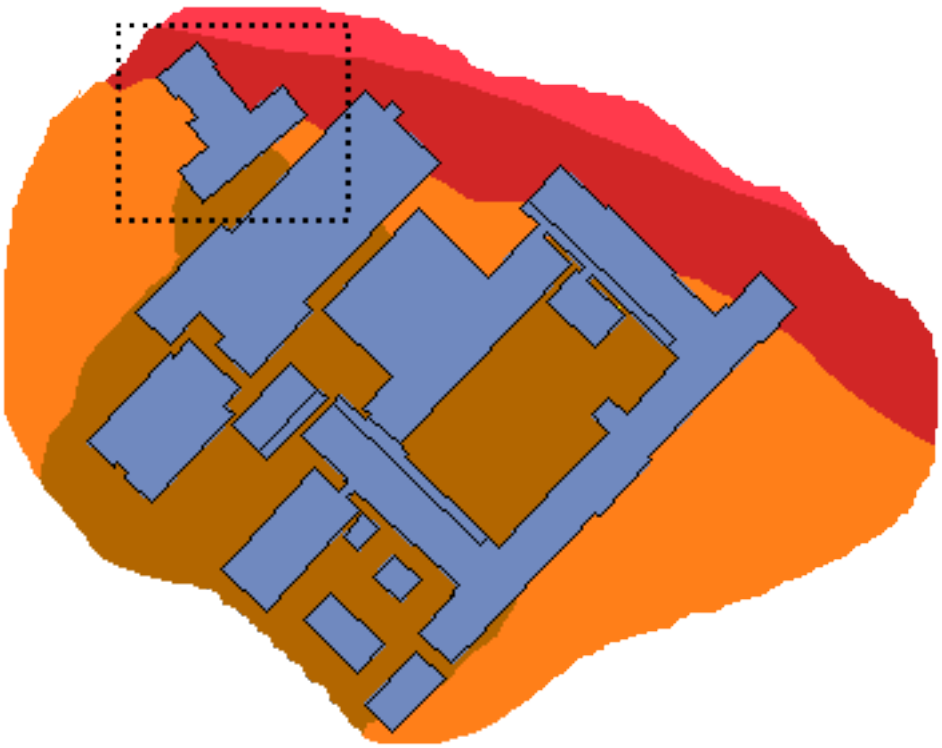
Figure 1. An example representing the standard data processing of a school noise map: (a) A typical noise map of a London secondary school [14]; (b) Matrix A, showing the noise distribution in the area marked with dotted lines in Figure 1a; (c) Matrix B, showing the environmental noise levels around the school buildings in the area marked with dotted lines in Figure 1a.

**Table 1** Comparison of environmental noise levels (dBA) of secondary schools between Inner London (30 sampled schools) and Outer London (66 sampled schools), where the significance level (2-tailed) are also shown, with ** indicates $p<0.01$ and * indicate $p<0.05$.

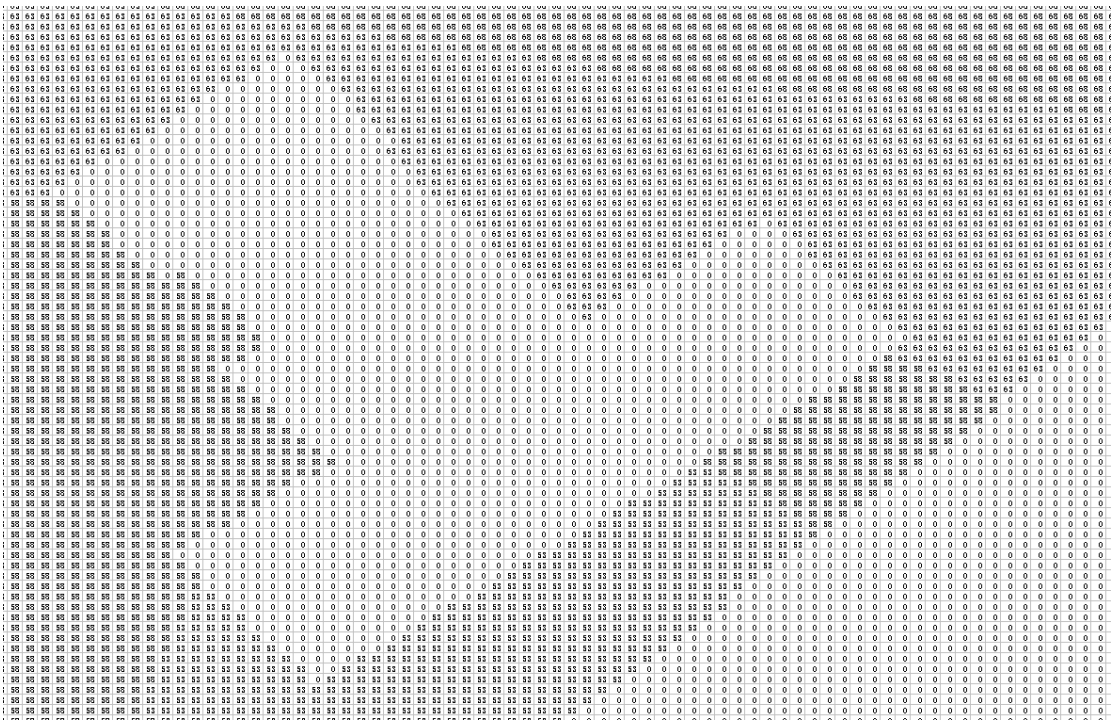
**Table 2.** Pearson and Spearman correlation coefficients between environmental noise levels of all secondary schools and academic achievement indicators, where the significance levels (2-tailed) are also shown (** indicates $p<0.01$ and * indicate $p<0.05$).

**Table 3.** Descriptive Statistics of environmental noise levels (dBA) of all the secondary schools and the road-side school group (25 sampled schools with greater noise levels).

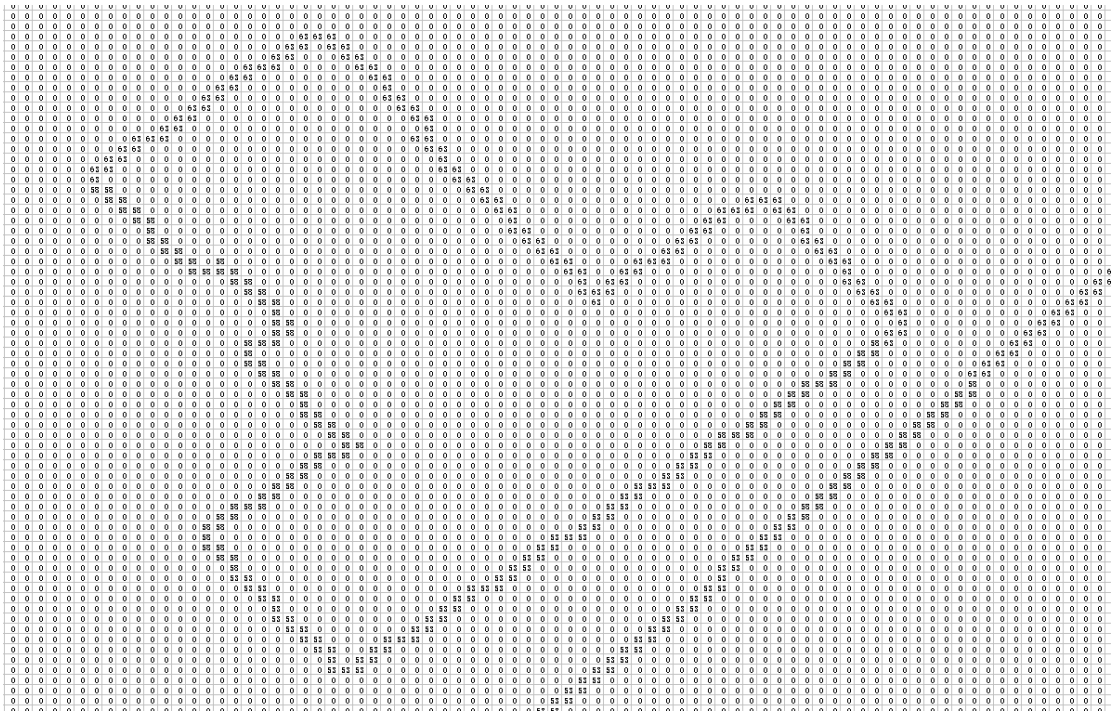
**Table 4.** Pearson and Spearman correlation coefficients between environmental noise levels of road-side school group and academic achievement, where the significance levels (2-tailed) are also shown (** indicates $p<0.01$ and * indicate $p<0.05$).



(a)



**(b)**



**(c)**

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| | Mean | | Standard deviation | | |
|---|---|---|---|---|---|
| | Inner London | Outer London | Inner London | Outer London | Mean difference |
| $L_{s\text{-}ave}$ | 51.6 | 49.8 | 4.67 | 5.02 | 1.8 |
| $L_{s\text{-}max}$ | 59.0 | 56.1 | 8.92 | 8.21 | 2.9 |
| $L_{s\text{-}min}$ | 47.2 | 46.3 | 2.92 | 3.73 | 0.9 |
| $L_{s\text{-}90}$ | 48.0 | 47.4 | 3.31 | 4.43 | 0.6 |
| $L_{s\text{-}10}$ | 57.3 | 53.7 | 8.25 | 7.50 | 3.6 (*) |

**Table 2.** Pearson and Spearman correlation coefficients between environmental noise levels of all secondary schools and academic achievement indicators, where the significance levels (2-tailed) are also shown (** indicates $p<0.01$ and * indicate $p<0.05$).

| | | Key Stage 4 score | CVA score | Overall absence | Persistent absence |
|---|---|---|---|---|---|
| Pearson | $L_{s\text{-}ave}$ | 0.056 | | -0.029 | -0.078 |
| Spearman | $L_{s\text{-}ave}$ | | 0.106 | | |
| | $L_{s\text{-}max}$ | 0.064 | 0.147 | 0.080 | 0.046 |
| | $L_{s\text{-}min}$ | 0.066 | 0.028 | -0.106 | -0.118 |
| | $L_{s\text{-}90}$ | 0.056 | 0.013 | -0.034 | -0.071 |
| | $L_{s\text{-}10}$ | 0.085 | 0.160 | 0.050 | 0.014 |

**Table 3.** Descriptive Statistics of environmental noise levels (dBA) of all the secondary schools and the road-side school group (25 sampled schools with greater noise levels).

| | | Number of sampled schools | Minimum | Maximum | Mean | Standard deviation |
|---|---|---|---|---|---|---|
| Road-side school group | $L_{s\text{-}ave}$ | 25 | 54.0 | 60.8 | 56.7 | 1.92 |
| | $L_{s\text{-}max}$ | 25 | 57.5 | 72.5 | 65.7 | 5.38 |
| | $L_{s\text{-}min}$ | 25 | 47.5 | 52.5 | 49.7 | 2.53 |
| | $L_{s\text{-}90}$ | 25 | 47.5 | 57.5 | 52.3 | 3.06 |
| | $L_{s\text{-}10}$ | 25 | 57.5 | 72.5 | 63.7 | 4.85 |
| All schools | $L_{s\text{-}ave}$ | 96 | 37.5 | 60.8 | 50.4 | 4.96 |
| | $L_{s\text{-}max}$ | 96 | 37.5 | 72.5 | 57.0 | 8.49 |
| | $L_{s\text{-}min}$ | 96 | 37.5 | 52.5 | 46.6 | 3.50 |
| | $L_{s\text{-}90}$ | 96 | 37.5 | 57.5 | 47.6 | 4.10 |
| | $L_{s\text{-}10}$ | 96 | 37.5 | 72.5 | 54.8 | 7.88 |

**Table 4.** Pearson and Spearman correlation coefficients between environmental noise levels of road-side school group and academic achievement, where the significance levels (2-tailed) are also shown (** indicates $p<0.01$ and * indicate $p<0.05$).

| | | Key Stage 4 score | CVA score | Overall absence | Persistent absence |
|---|---|---|---|---|---|
| Pearson | $L_{s\text{-}ave}$ | -0.172 | -0.267 | 0.169 | 0.193 |
| | $L_{s\text{-}max}$ | -0.144 | 0.054 | 0.229 | 0.335 |
| | $L_{s\text{-}10}$ | -0.215 | -0.002 | 0.298 | 0.417(*) |
| Spearman | $L_{s\text{-}min}$ | 0.123 | -0.073 | -0.129 | -0.157 |
| | $L_{s\text{-}90}$ | -0.053 | -0.343 | -0.132 | -0.254 |