

# A systematic review of evidence of the effect of transport noise interventions on human health.

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## ABSTRACT

This paper describes a systematic literature review (1980-2014) of evidence on the effects of transport noise interventions on human health. Sources considered are roadways, railways, and air traffic. Health outcomes include sleep disturbance, annoyance, cognitive impairment of children and cardiovascular diseases. The interventions reviewed covered all noise management or control strategies practiced for all sources of transport noise. A previously developed model was applied to categorise studies. The review shows that evidence is thinly spread across different sources, outcomes and intervention types. While meta-analysis of the association between changes in level and outcome was not possible, some 43 individual transport source studies were examined as to whether the intervention lead to a change in health outcome and (for source, path and infrastructure change interventions) if the observed change in outcome was of a magnitude at least equivalent to that which would be predicted from a relevant exposure-response function, or exhibited excess response. The review showed that diverse intervention study designs, methods of analyses, exposure levels, and changes in exposure, restricted the analysis of findings. Further studies of transport interventions should be based on a protocol of measuring change in exposures, outcomes and confounders, not just change in noise levels.

## 1. INTRODUCTION

The different noise sources, and the different types of interventions possible for each source, introduce considerable complexity into a systematic review of evidence of the effects of environmental noise interventions on human health. To provide structure to this review we use a conceptual model for such interventions suggested by (Brown and van Kamp 2015) showing different types of interventions along the causal path between noise sources and human outcomes and measurement points along the pathway where changes relevant to human outcomes can be measured. This model builds on frameworks from the air pollution field that have been utilized to evaluate whether actions taken to improve air quality have resulted in reduced health effects – so-called air pollution accountability research (NRC 2002),(HEI 2003)(Van Erp et al, 2012),(Burns et al 2014). However, the frameworks used for air pollution put emphasis on ambient concentrations of the pollutants. This is not appropriate for environmental noise where exposure of people is strongly influenced by the length and nature of the propagation paths from sources to receivers, and hence highly dependent on the disposition of receivers relative to the sources. For the consideration of environmental noise interventions, the propagation path thus needs to figure as a significant component of the system between sources and humans. The circles of Figure 1, show the components in the basic system between environmental noise sources and human health, generic to all sources of environmental noise.

Another difference is that air pollution accountability research has tended to focus on regulatory interventions directed at reducing emissions; examining whether this type of intervention consequently reduces ambient concentrations over time. While regulatory intervention is also used in managing environmental noise, for example by control of aircraft or road vehicle source levels, this is only one of a set of possible environmental noise interventions. Environmental noise management, or environmental noise control, often involves technical interventions that include not only reduction of levels at the source but also the positioning of outdoor barriers between source and receivers, and changes in the acoustic properties of building envelopes to reduce levels at receivers. It also includes other source-related changes such as time restrictions on operations of sources, or changes in infrastructure. Examples of the latter include the opening or closure of new roadways and railway lines, bypass roadways, or the opening of new airports/runways and consequent rearrangement of air traffic load on different flight paths. Environmental noise management has also utilized interventions that can be considered behavioral: promoting behavioral change that reduces peoples' exposures or that is directed at mitigating their adverse reactions to exposure.

Based partly on the available intervention literature selected for further analysis and experience, five broad categories of environmental noise intervention have been identified (Table 1). Such categorization of interventions is necessary as compilation of evidence regarding outcomes from interventions may only be appropriate when the evidence is from studies that belong to the same category. In addition to their listing in Table 1, the Intervention Types have been incorporated into the framework of Figure 1, indicating where each action fits along the system pathway between sources and human health outcomes. The framework proposed in Figure 1 provides a systematic and comprehensive basis for any future work with respect to the effects of environmental noise interventions.

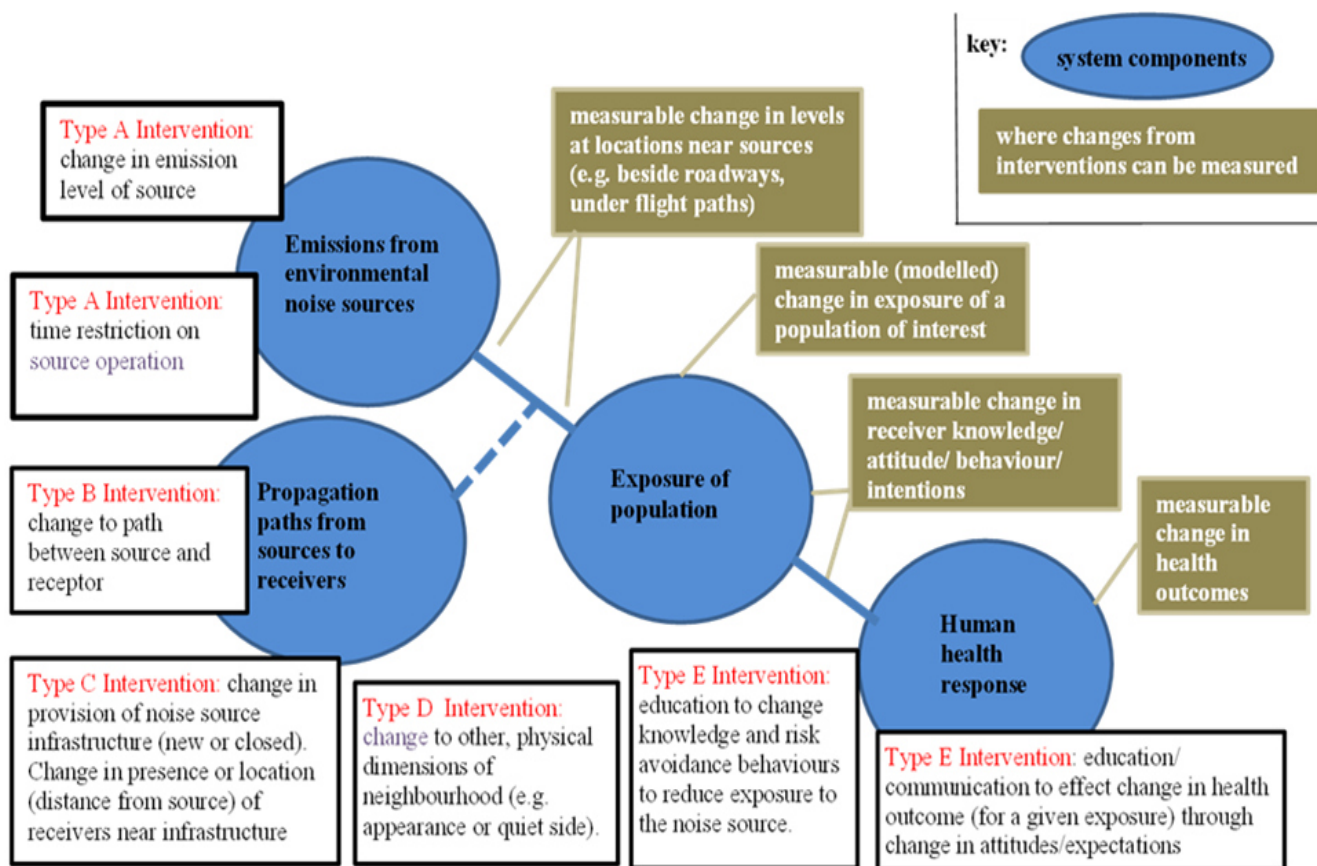


Figure 1 - Intervention framework, with different types of intervention and where outcomes can be measured, shown on the system components of the path between environmental noise and human health

Terminology for two of the technical interventions has been borrowed from the environmental noise control field (source interventions and path interventions). A third category of intervention is termed new/closed infrastructure. A fourth category is termed other physical interventions, and the fifth category referred to as change in behavior interventions. The categories and sub-categories of these intervention types are largely self-explanatory, but they are also illustrated by examples in Table 1.

## 2. METHOD

### 2.1 Literature Searches: Prior Reviews

Various prior reviews of papers on interventions had been located, and the search for individual intervention studies (Section 2.2 below) identified seven further narrative review papers. They provided useful insights into the limited body of work available on environmental noise interventions.

Table 1 - Categorization of Environmental Noise Interventions

Type	Intervention Category	Intervention Sub-category	Examples
A	Source interventions	change in emission levels of sources	motor vehicle emission regulation; playback levels personal listening devices; rail grinding; road surface change; change in traffic flow on existing roadways/railways; change in number of aircraft flights
		time restrictions on source operations	airport curfew, heavy vehicle curfew
B	Path interventions	change in the path between source and receiver	noise barrier
		path control through insulation of receiver/receiver's dwelling	insulation of building envelope; wearing of ear protectors
C	New/closed infrastructure	opening of a new infrastructure noise source, or closure of an existing one	new flight path; new railway line; new town road bypass; new wind farm; or closure of any of these
		planning controls between (new) receivers and sources <sup>2</sup>	urban planning control; 'buffer' requirements <sup>2</sup>
D	Other physical interventions	change in other physical dimensions of dwelling/neighborhood	availability of a quiet side; appearance of the neighborhood, availability of green space etc.
E	Change in behavior interventions	change in individual behavior to reduce exposures; avoidance or duration of exposure	education regarding playback levels on personal listening devices, or potential hearing damage through loud music
		community education, communication	changing opinions regarding sources, or explaining reason for noise changes

<sup>1</sup>Intervention Type C is introduced to categorize situations where noise levels from a source have changed from (say) non-existent to high because of new infrastructure.... e.g. little road traffic to now being beside a newly opened freeway; or in an area now under a new flight path where previously there had been no overflights; or where a new roadway is constructed. Type C interventions also include the converse: where, say, road traffic noise drops from a high level because a roadway had been closed, or aircraft noise is eliminated because an airport runway has been shut. Of course, changes in transport infrastructure may produce consequent changes in traffic load on other parts of the network – leading to changes (increases or decreases) in source levels - but these are best categorized as Type A Source interventions as they are changes in levels from an existing source. Type C is intended to describe interventions where a (completely) new source is introduced, or an existing one removed – though the distinction will sometimes be blurred.

<sup>2</sup>Just as Intervention Type C describes opening a new noise source (say, roadway near an existing dwelling), we extend this category to also incorporate building a new dwelling near an existing noise source. In an urban planning sense, a noise 'intervention' that may be used is the requirement of some minimum distance between existing noise source and new residential development. The effect of such an intervention could be measured by comparing human outcomes in newly constructed dwellings at different propagation distances from the same noise source.

**2.2 Literature Searches: Search for Individual Studies**

With the help of a professional librarian of The Netherlands National Institute for Public Health and the Environment, we performed search runs on the following data sets:

- SBAS Scopus
- ME66 MEDLINE
- EM74 EMBASE
- PI67 PsycINFO
- IN73 Social SciSearch
- IS74 SciSearch
- BA70 BIOSIS Previews
- NLM
- 2014 Elsevier B.V.
- AM. PSYCH. ASSN. 2010
- Thomson Reuters
- Thomson Reuters
- Thomson Reuters

The search string, was refined and adapted for the different data bases (not shown). The search was restricted to publication years 1980-2014. Excluding duplicates, this search resulted in 448 articles. After examination of these search results and various consultations, we asked our professional librarian for an additional search, training the search by reference to specific papers located in the first search and to various relevant papers recognized to be missing from it. This resulted in 61 additional articles identified, including some duplicates. A further 36 articles were identified through personal communications and from the additional narrative reviews.

The resulting 545 titles, keywords and abstracts were examined by each of the authors independently to identify papers that were to be read in full, based on the following criteria: (a) the paper dealt with environmental noise sources ... rail, road, aircraft, wind turbines, personal electronic devices, other...and specific settings... residential, school, hospital, public venues, other, and (b) reported a study of an intervention. The result was agreement to examine the full text of 116 papers.<sup>1</sup> We restrict our reporting in this current paper to the subset of environmental noise studies related to transport sources, resulting in 43 reports of transport related interventions considered further in this paper. The distribution of these studies across noise sources, outcomes and intervention types is in Table 2.

Table2 Number of individual studies within each group (noise source x outcome x intervention type)

	# Peer Reviewed	# Non-Peer Reviewed Papers	Total Papers per Group
<b>ROAD TRAFFIC NOISE SOURCES</b>			
<b>Outcome: Annoyance</b>			
A Source Intervention	7	3	10
B Path Intervention	4	2	6
C New/Closed Infrastructure	1	1	2
D Other Physical	6	1	7
<b>Outcome: Sleep Disturbance</b>			
A Source Intervention	1	-	1
B Path Intervention	1	1	2
C New/Closed Infrastructure	2	-	2
D Other Physical	1	-	1
<b>Outcome: Cardiovascular Effects</b>			
D Other Physical	4	-	4
<b>AIRCRAFT NOISE SOURCES</b>			
<b>Outcome: Annoyance</b>			
B Path Intervention	1	-	1
C New/Closed Infrastructure	2	1	3
<b>Outcome: Sleep Disturbance</b>			
C New/Closed Infrastructure	1	1	2
<b>Outcome: Cognitive Development in Children</b>			
C New/Closed Infrastructure	1	-	1
<b>RAIL NOISE SOURCES</b>			
<b>Outcome: Annoyance</b>			
A Source Intervention	-	1	1
C New/Closed Infrastructure	1	-	1
E Education/Communication	-	1	1
NOTE: studies that reported on more than one outcome are included under each outcome. Papers that duplicate the reporting of individual studies have been excluded.			

<sup>1</sup> (details of keywords and flowchart of search as well as a full reference list can be obtained via the authors)

### 2.3 Examination of Individual Studies

The majority of the intervention studies included (Table 2) were for road traffic noise sources (thirty three studies); fewer for aircraft noise (seven studies) and rail traffic noise (three studies). The principal change in health outcomes reported was annoyance (30 studies), fewer of sleep disturbance (eight studies), cardiovascular effects (four studies) and cognitive development in children (one study). Overall there is a restricted evidence base on the health effects of transport noise interventions, spread across sixteen different groupings (grouped by source type, health outcome, and intervention type) of transport noise intervention studies. Excluding “Other Physical” interventions because, for these, the evidence of the effect on health was indirect, only two of these groupings, source interventions and path interventions for road traffic for the annoyance outcome, have more than three entries.

Intervention studies can be difficult to conduct, but a number identified in the review were of good quality. However, there was significant diversity between individual studies in terms of study designs, methods of analyses, exposure levels and changes in exposure experienced as a result of the interventions. In some studies, the changes in noise exposure were variable across participants (sometimes reported in aggregate) and were not always adequately linked to the corresponding change in outcomes. Methods of analyses and reporting were also highly varied across studies. For these reasons, a meta-analysis of the association between change in exposure resulting from the interventions and change in health outcomes was not possible.

Instead, given that we could not undertake a pooled quantitative analysis of the strength of association between interventions and outcomes, we sought instead to use the evidence presented within each of the individual studies to qualitatively answer two questions with respect to the effect of environmental noise interventions. The questions were: 1) Did the study demonstrate that the intervention lead to a change in health outcome? 2) For source, path and infrastructure change interventions, if there was a change in health outcome, was the observed change in outcome of a magnitude at least equivalent to that which would be predicted from a relevant exposure-response function (ERF), based on the observed change in exposure?

In examining the first question, we did not assess the magnitude of the change for each individual study (it is recorded if available), but looked instead to evidence within that study that health outcomes changed in association with the intervention. While this question is a minimal test of the consequence of an intervention, it contributes to answering an important policy question: Do environmental noise interventions change health outcomes?

The second question referred to a relevant ERF. In the individual studies the relevant ERFs, (all for the annoyance outcome, except for sleep disturbance in one study) were:

- 1) an ERF based on the responses to the before (steady-state) exposure conditions in that particular study (using grouped response data or individual responses), or sometime separate ERFs for both before and after states (5 studies used an ERF of this nature);
- 2) an ERF reported from similar situations to those in the particular individual study, as determined by the study authors (4 studies used an ERF of this nature) a previous synthesis of ERFs.
- 3) The particular ERF chosen depended on the date of the study: namely: (Schultz 1978), (2 studies); (FICON 1992), (1 study); (Miedema and Vos, 1998), (2 studies); (Miedema and Oudshoorn 2001) or (European Commission 2002), (3 studies).

We compared the magnitude of the observed change in health outcome to the magnitude of the change that would be ‘predicted’ from the same change in exposure on the relevant ERF. If the observed health outcome changed similarly to the ERF-predicted change, the conclusion was that the ERF could have reliably estimated the magnitude of the response to the intervention given the magnitude of the change in exposure. If the observed change was greater, then the study reported an excess response to the change (Brown & van Kamp 2009a). The observations provide guidance to another important policy question: Can the magnitude of the effect of an intervention be estimated from a relevant ERF?

### **3. SELECT OBSERVATIONS FROM THE REVIEW**

#### **3.1 Overview of Change in Health Outcomes**

The exposure-related interventions in most of the transport noise studies were associated with a decrease in transport noise exposure. However, in five studies (four road traffic noise studies and one aircraft noise study) some or all of the participants experienced noise exposure increases. Observations below with respect to change in responses apply equally to the increases as they do to the decreases.

Nearly all of the individual studies, irrespective of noise source, health outcome or intervention type, show that the intervention led to a change in the aggregate health outcome of those who experienced the intervention. Excluding those studies for which no observation was appropriate (because there was no change in exposure, or the study was a follow-up survey at some interval after the original) there was only one transport study reporting no change in health outcomes. In summary, based on the available findings, interventions of all types, and for all transport sources, consistently have an effect on health outcomes. The caveats to this observation are that it is based on a limited number of studies overall, and there is unequal distribution of the studies across noise sources. The majority of the studies are for road traffic noise; less for aircraft noise and rail traffic noise.

A further, 17 studies (of source, path and new/closed infrastructure interventions) for road and aircraft noise sources, and for the annoyance outcome, reported that the minimum magnitude of the change in annoyance could have been predicted from a relevant exposure-response function. All but two of these also found there to be an excess response - a change effect in addition to the exposure effect predicted by an ERF (Brown & van Kamp 2009a). One aircraft noise intervention study found that the magnitude of the change in sleep disturbance outcomes could have been predicted from an ERF for sleep-disturbance.

These are consistent findings regarding the magnitude of the observed change in health outcome. However there are again important caveats: namely that the evidence on relationship of observed change with an ERF was available only in studies of road traffic noise sources (and a small number of aircraft noise studies) and largely only for the annoyance outcome.

The available evidence is too poorly conditioned across different group of studies to be able to test for any differences in change in health outcomes arising from different types of interventions.

### **4. IMPLICATION FOR FUTURE STUDIES AND NOISE MANAGEMENT**

#### **4.1 Future Studies**

There are many examples in the noise management/control literature of interventions which report a change in noise emissions from sources, or a change in noise levels in various locations, but these do not help elucidate the relationship between interventions and health unless they also reported changes in exposures of affected populations and changes in health outcomes or the beneficiaries. The systematic review of the literature identified 43 published intervention studies that reported observed changes in health outcomes together with observed changes in peoples' exposures. Of the 43 transport noise studies, 77% were for road traffic noise, with fewer for aircraft noise (16%) and rail traffic noise (7%) – with the majority of them (70%) reporting annoyance outcomes. Further studies directly linking transport noise interventions to health outcomes are required, particularly for aircraft and rail noise sources, and for human health outcomes other than annoyance.

#### **4.2 Designs and Analysis**

We recognize the difficulty in doing so in many intervention studies, but precise specification of the change in exposure for individuals, or subgroups, is required. In part to encourage this, we suggest that there are advantages in following the approach, used in two of the individual aircraft noise studies (Brink et al 2008),( Breugelmans et al, 2007) of reporting both the noise exposure before the intervention, and change in noise exposure as a result of the intervention, of the study participants, and using both in the analysis.

Other observations arising from the systematic review included that future intervention studies should use validated, and where possible, harmonized, measures of exposures and outcomes as well as of moderators and confounders. Most interventions result in step changes in exposure with expected step changes in human response to this change. While many intervention studies used a before and after design, there has generally been insufficient consideration that the change in human response to a step change in exposure may have a different time course to that of the change in exposure. A protocol is required for the conduct of future intervention studies that provides longitudinal assessment of both exposure and human response, and (Brown and van Kamp 2005)

reported a design that is suitable (included here as Table 3). With a change in noise exposure over the interval between t0 and t1, sequential measurements of effect should be made before and after the change, preferably with multiple after measurements (A-1, A0, A1, A2 , ... Ax). Repeated measurements should also be made of activity interference (Actx), potential confounders such as noise sensitivity (Sensx), coping strategies (Copx), and a range of other attitudinal, retrospective, and prospective, assessments. In addition, that model incorporates steady-state controls into the study design. The protocol in Table 3 is specific to studies of the effect of interventions on annoyance, but the principles of longitudinal measurements of exposure, of responses, and of potential confounders, can be adapted readily to studies of other human outcomes .

We suggest that authorities proposing interventions, whether those are at local, national or international level, and whether or not the primary purpose of the intervention concerns noise, should be encouraged to include significant funding for the design and implementation of studies to evaluate outcomes from the interventions. At present many of the evaluations appear to be afterthoughts. The effect of the intervention on the exposure of defined populations needs to be assessed, and its effect on the health outcomes of the same populations - not just the changes in noise levels that result from the intervention. We note a potential impediment is that some government and private instrumentalities who initiate noise intervention programs may have little interest in undertaking an evaluation of that intervention once a decision to implement it has been taken – avoiding any possible reputational risk that could be associated with a costly intervention later being shown to have little effect on human health. We also note the potential for an associated bias (though we have no evidence of it): publication bias may have influenced the findings of the systematic review in that intervention studies that failed to find a change in human health outcomes may tend to go unreported compared with those that did find a change.

Table 3 Model protocol for intervention studies. After (Brown and van Kamp 2005)

<b>Sequential Measurements</b>	<b>before-1</b>	<b>before0</b>	<b>after1</b>	<b>after2 ...</b>
Time	t-1	t0	t1	t2 ...
noise exposure	L-1	L0	L1	L2 ...
<b>Effect Measures (or Respondent Attribute Measures)</b>				
annoyance	A-1	A0	A1	A2
activity interference	Act1	Act0	Act1	Act2
retrospective annoyance			RA011	RA02
noise sensitivity	Sens-1	Sens0	Sens1	Sens2
attitudes to authorities etc.	Ats-1	Ats0	Ats1	Ats2
opinion of neighbourhood	Neigh-1	Neigh0	Neigh1	Neigh2
coping strategies	Cop-1	Cop0	Cop1	Cop2
prior knowledge	...	X102	...	...
expectations	...	Y102	...	...
<b>Steady-state Controls</b>	Before Control		After Control	

### 4.3 Implications for noise management and policy

Table 2 showed that nearly all interventions led to a change in the aggregate health outcome of those who experienced the intervention, irrespective of the source type and irrespective of the type of intervention. There was only 1 study which did not conclude on a change in effects. The consistency of the finding across nearly all of the transport noise interventions is a general assurance that the noise management strategies that are currently utilized have, at least, the potential of a beneficial effect on human health. The caveat to this positive finding is that the evidence is not extensive or well distributed over all transport noise sources, intervention types, or health outcomes, and of course this minimal test says nothing about the magnitude of the interventions in improving health outcomes. Seventeen studies (these included source, path and new/closed infrastructure interventions) for road and aircraft noise sources, reported that the minimum magnitude of the change in annoyance outcomes matched that estimated from a relevant exposure-response function (ERF) and the given change in exposure. Again this is a useful confirmation of current noise management approaches. It supports policy and planning as relevant

annoyance ERFs for road (and possibly aircraft) noise can provide at least a starting point for the health impact assessment of future interventions.

The current systematic review of the effects of interventions demonstrates the existence of a change effect for annoyance in a high proportion of the studies of source, path and infrastructure change interventions for road and aircraft noise. It does not, however, help resolve which of the different plausible explanations are the cause of the phenomenon.

There is also no clear evidence with respect to thresholds regarding changes in health outcomes as a result of interventions. Interventions thresholds could have two dimensions: 1) the smallest change in exposure levels that result in a change in outcome, and 2) the minimum before-level. The only observation we can make is that several interventions that reduced noise exposures by 1 to 2 dB (energy-based scales) did not result in any observed change in health outcomes.

There is little evidence available with respect to the longitudinal path of health outcomes changes following the initial change resulting from an intervention, none of it suggests the initial change in response is not sustained over, at least, several years. In other words, there is no evidence of adaptation in the outcome arising from the intervention. Here adaptation refers to attenuation in the after-change outcome subsequent to the intervention – not its regression to levels of the outcome that existed before the change. In any examination of adaptation/habituation it is important that terms are adequately defined as there is ambiguity in the way different authors use these terms. (Brown and van Kamp 2009b) provide discussion on this topic.

The studies of 'other physical interventions' (such as the provision of a quiet side to the dwelling, or the provision of green space in the neighbourhood) were not intervention studies per se as they did not provide direct evidence of an intervention. Instead they provide comparisons of health outcomes from groups with and without the particular physical dimension of interest. These 'other physical interventions' did, in the majority of studies, demonstrate the efficacy of potential interventions of this sort, but it must be noted that this is indirect evidence consisting of comparison of outcomes of different groups under different conditions, rather than before-after comparisons on the same group.

Finally, there is a range of systems-wide matters that additionally should be considered in future evaluations of the health outcomes of transport noise interventions. These are important as they provide, in contrast to most of the evidence which is based on a specific intervention within specific space and time bounds, a more systems-wide understanding of transport noise interventions that is likely to be important in any comprehensive evaluation of the human health effects of transport noise interventions. Details are described elsewhere (Brown & van Kamp 2016).

## 5. LIMITATIONS

There are many examples in the noise management/control literature of interventions which report a change in noise emissions or in noise levels, but in the absence of reporting of change in health outcomes or of exposures, these do not elucidate the relationship between interventions and health.

The consequence is that there is a restricted evidence base on the health effects of environmental noise interventions, spread across sixteen different groupings (grouped by source type, health outcome, and intervention type) of transport noise intervention studies. Only two of these groupings - source interventions and path interventions for road traffic for the annoyance outcome - have more than three entries. Publication bias may have influenced the findings of this review: intervention studies that failed to find a change in anticipated human-response outcomes may have had a lower probability of publication than studies that did reported outcomes did change as a result of the intervention. We also suggest, that many government and private instrumentalities (e.g, airport authorities, road authorities, planning departments) who initiate noise intervention programs may have little interest in undertaking an evaluation of that intervention once the decision has been taken to fund and implement noise management measures. The environmental noise intervention studies included in this review were focused on the site of the intervention. There are also systems-wide factors that need to be considered in any comprehensive evaluation of the human health effects of environmental noise interventions.

Further studies directly linking transport noise interventions to health outcomes are required, particularly for aircraft and rail noise sources, and for human health outcomes other than annoyance. A protocol is recommended for the design of future studies.



## 6. CONCLUSIONS

This systematic review of the literature, 1980 to 2014, shows that overall there has been a limited number of intervention studies published that report observed changes in health outcomes or observed changes in peoples' exposures along with quantitative details on the association between change in exposure and change in human health effects. The majority of these are for road traffic noise sources; fewer for aircraft noise and rail traffic noise. The principal change in health outcomes assessed was annoyance, with fewer of sleep disturbance, cardiovascular effects and cognitive development in children.

Intervention studies can be difficult to conduct, but a number of those identified in this review were of good quality. Diversity between studies, and within groups, in terms of study designs, methods of analyses, exposure levels and changes in exposure experienced hindered a meta-analysis across studies examining the association between changes in level and changes in outcome was not possible. However, the available evidence was that transport noise interventions changed the health outcomes reported by those who experienced the intervention, irrespective of the source, the outcome or the intervention type (for the sources, outcomes and interventions represented in the studies reviewed here).

There was also evidence regarding the magnitude of the change in health outcomes, though this is available only for the annoyance outcome and only for road traffic sources and aircraft noise sources. The minimum magnitude of the change in annoyance outcomes as a result of the interventions can be predicted using a relevant exposure-response function. Further, in the majority of these studies, the magnitude of the change in response to an intervention exhibited a change effect - an excess response in addition to the level effect predicted using an ERF.

In general we can state that interventions at the source, in the pathway and intervention in infrastructure (Types A to C) are effective in reducing annoyance. Often a positive change effect is observed: the reduction is larger than could be expected based merely on noise levels. There are indications that this change effect remains stable over time.

Studies into the effect of indirect measures (Type D) show that a difference of at least 10 dB between the least and most exposed facade can lead to a considerable differences annoyance. This is dependent on use of the quiet room as well as on visual aspects.

When interpreting the results, the influence of contextual, situational personal factors has to be accounted for (noise sensitivity, distance to the road, availability of a quiet side and window opening behavior, context, expectations about effectiveness of the intervention and satisfaction with residential area).

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