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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 of the effects of transport noise interventions on human health. The sources considered in this paper 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. The categorization and conceptual framework of interventions is drawn builds on that for environmental noise described in Brown and van Kamp (1). The finding of the systematic review is that the evidence is thinly spread across different sources, outcomes and intervention types. While meta-analysis of the association between changes in level and changes in 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.

Keywords: Noise, Interventions, health effects I-INCE Classification of Subjects: 62.5, 13.1, 13.2

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 (1) 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 (2)(3)(4) (5). 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. Figure 1 shows 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 (e.g. 6, Chapter 5). 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

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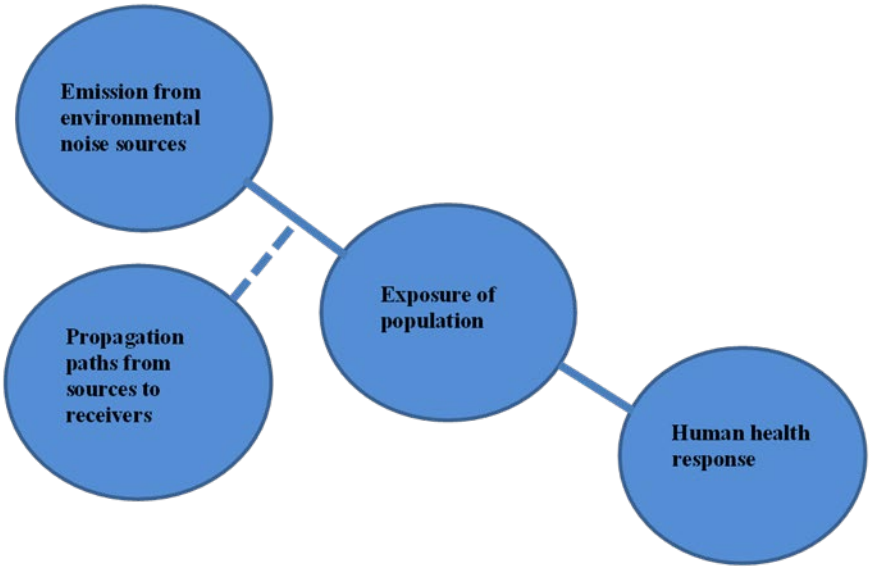

Figure 1 - System components of the path between environmental noise and human health.

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 below, but also on the experience of many decades of environmental noise management, 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 2, indicating where each action fits along the system pathway between sources and human health outcomes. The framework proposed in Figure 2 provides a systematic and comprehensive basis for any future work with respect to the effects of environmental noise interventions.

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 controls2 between (new) receivers and sources	urban planning control; 'buffer' requirements2
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

[1] 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.

[2] 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	NLM
EM74	EMBASE	2014 Elsevier B.V.
PI67	PsycINFO	AM. PSYCH. ASSN. 2010
IN73	Social SciSearch	Thomson Reuters
IS74	SciSearch	Thomson Reuters
BA70	BIOSIS Previews	Thomson Reuters

The search string, was refined and adapted for the different data bases and is summarized in Table 3. 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.

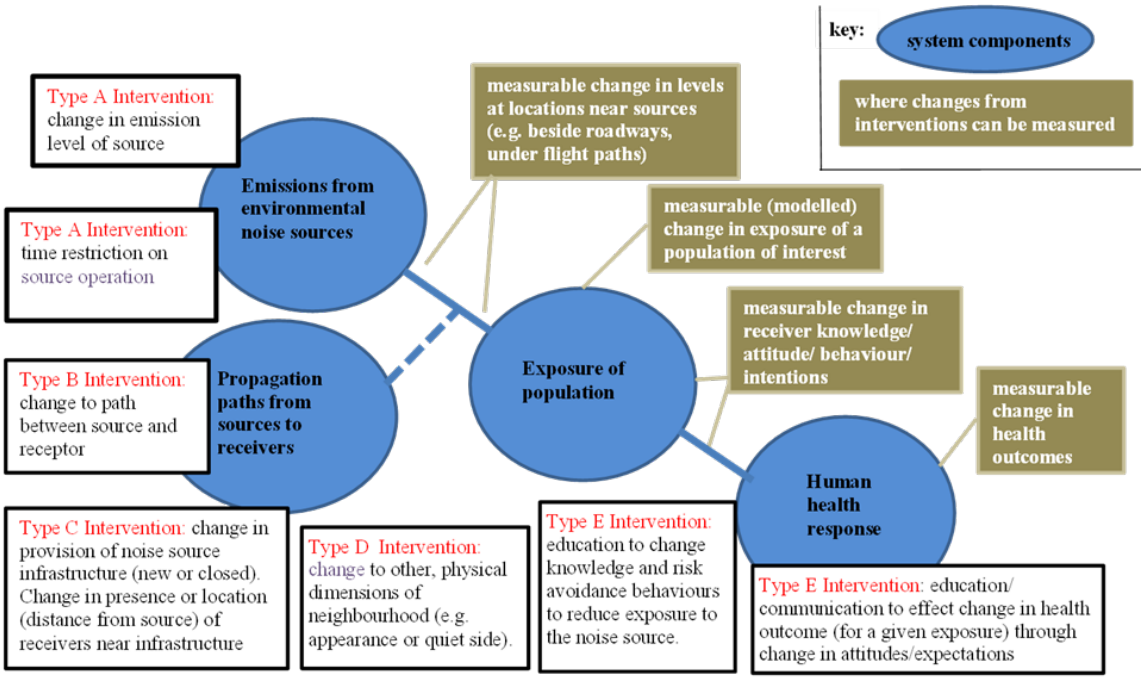

Figure 2 - Intervention framework, with different types of intervention and where outcomes can be measured

Table 3 - Key search terms (in title, abstract and/or keywords)

Exposure	1 noise*or (((noise sensitivity or noise perception) or noise/) and (hearing or sound*). 2 (traffic or transport* or road or roads or road-traffic or road-transport or automobile* or vehicle* or vehicular movements or motorcycle* or tram or train or trains or railway* or railroad* or airplane* or aeroplane* or aircraft* or airport* or air-traffic or nightflights or night flights). 3 exp transportation/ or exp motor vehicles/ or exp railroads/ or exp aviation/ or environmental exposure/ or environmental health/ or environment 4 (environment or environmental or windfarm* or wind farm* or windmill* or wind turbine* or wind park* or wind turbine* or turbine noise*). 5 (music or electronic devices* or listening devices or headphone* or festival* or disco* or recreation* or leisure) or recreation/ or leisure activities/ 6 (hearing loss, noise induced/ 7 1 and (2 or 3 or 4 or 5 or 6) 8 (noise pollution or noise exposure).ti. or transportation noise
Health effects	9 adverse effects. (annoyance or disturbance or nuisance or bother*). 10 (health or mortality or morbidity or wellbeing) or health/ or health status/ or mental health/ or quality of life/ or public health/ 11 (stress or asthma or respiratory or blood pressure or heart rate* or cardiovascular).tw. or stress, psychological/ or stress, physiological/ or emotions/ or asthma/ or child behavior/ or blood pressure/ or heart rate/ 12 (cognitive performance or cognitive impairment or cognition or cognitive development or cognitive effects or memory or recognition or loudness perception or reading or pre-reading or school performance or performance or comprehension or annoyance or (disturbance adj3 daily activit*) or emotion* or stress or perception or speech or intelligibility or hearing impairment or hearing loss or tinnitus) 13 cognition/ or cognition disorders/ or memory/ or reading/ or

	mental recall/ or recognition, psychology/ or loudness perception/ or perception/ or auditory perception/ or comprehension/ or adaptation, psychological/ or speech intelligibility/ or hearing disorders/ or hearing loss/ or tinnitus/ 14 (sleep or insomnia or awakening*)or exp sleep/ or exp sleep disorders/ or sleep deprivation/ or wakefulness/ 15 (reproductive outcome* or pregnancy outcome* or birth outcome* or birth weight) or pregnancy outcome/ or birth weight/ 16 (7 or 8) and (9 or 10 or 11 or 12 or 13 or 14 or 15)
Intervention	17 (prevention or preventive or prevent or preventative or preventing or intervening or intervention* or mitigation or measures or reduction or reducing or reduce or improving or minimizing or program* or campaign* or project* or policy or policies or strategy* or guidelines or directive* or community response or public health response)
Design	No restrictions
Time period	1980-2014
Language	No restrictions

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. The process leading to the identification of the 116 papers for full-text review from the 545 titles is summarized in Figure 3.

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 4.

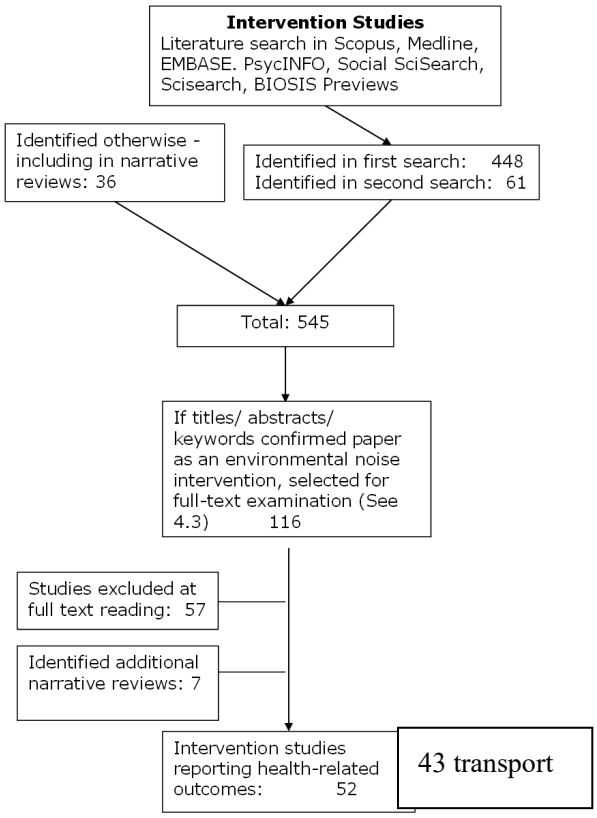

Figure 3 – Summary of search results: 43 of the 52 intervention studies located were of transport sources.

Table 4 - Number of individual studies within each group (noise source x outcome x intervention type)

	# Peer Reviewed Papers	# Non-Peer Reviewed Papers	Total Papers per Group
ROAD TRAFFIC NOISE SOURCES			
Outcome: Annoyance			
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
Outcome: Sleep Disturbance			
A Source Intervention	1	-	1
B Path Intervention	1	1	2
C New/Closed Infrastructure	2	-	2
D Other Physical	1	-	1
Outcome: Cardiovascular Effects			
D Other Physical	4	-	4
AIRCRAFT NOISE SOURCES			
Outcome: Annoyance			
B Path Intervention	1	-	1
C New/Closed Infrastructure	2	1	3
Outcome: Sleep Disturbance			
C New/Closed Infrastructure	1	1	2
Outcome: Cognitive Development in Children			
C New/Closed Infrastructure	1	-	1
RAIL NOISE SOURCES			
Outcome: Annoyance			
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.			

2.3 Examination of Individual Studies

The majority of the intervention studies included (Table 4) 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)
3) a previous synthesis of ERFs. The particular ERF chosen depended on the date of the study: namely: Schultz (7) (2 studies); FICON (8) (1 study); Miedema and Vos, (9) (2 studies); Miedema and Oudshoorn, (10) or European Commission (11) (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 e*xcess response* to the change (see Brown and van Kamp, 2009). The observations provide guidance to another important policy question: *Can the magnitude of the effect of an intervention be estimated from a relevant ERF?*

Table RA1 SOURCE INTERVENTIONS [Type A]

Red text indicates tested to be statistically significant

Abbreviations used in all subsequent tables:

B	Before-study	ERF	Exposure response function	n.a.	not applicable or not available
A	After-study	P(s)	Participant(s)	CI	confidence interval
ISO	ISO annoyance scales (ISO_TS_15666_2003)	mo(s)	month(s)	Q	questionnaire
%HA	Percentage Highly Annoyed	yr(s)	year(s)	s.d.	standard deviation
B/A	Before and After study	SE	standard error		

Authors	Intervention & Study		N, Response Rate & Method	Exposure Levels		Change in levels and distribution of change across Participants	Outcome measure(s) Before and after outcomes	Did outcome change with change in exposure? Yes/No (significance tested?)	Before/after outcome change compared to that estimated from an ERF	Comments	Confounders adjusted for in analyses
	Nature	Design		Before	After						
Brown (2015)	Brisbane. Truck restriction, change in traffic composition	B/A. Five rounds of after surveys out to 20 mos.	99 in panel Response rate 84%. ~20% of panel drop out each survey round. Interviews	65-73 L_{den} 60-68 L_{night} 69-77 $L_{10,18h}$ Measured	65-73 L_{den} 60-68 L_{night} 69-77 $L_{10,18h}$ Measured	No change in L_{den}, L_{night} or $L_{10,18h}$ - but see comments All Ps experienced same change - but were exposed to different before levels	%HA based on 7, 8 & 9 of ISO (but with 0-9 scale). B: 58% HA A: 33%, 18%, 18% HA respectively at survey rounds 2, 3 & 4 Mean Annoyance also reported	n.a. as no change in L_{den} exposure (but there was a change in number of noise events) **Est. Marg. Mean annoyance scores changed significantly over period of truck restriction (F4,170.4=12.18, p<.001)** (see comments)	ERF cited was Miedema & Oudshoorn (2001). 58%HA in before-study much higher than estimated by ERF (latter is 16% to 30% for L_{den} over the range of Ps' exposures. No observation possible on the relationship of change in outcomes with the ERF because L_{den} did not change.	Change in response attributed to change in number of noise events	Noise sensitivity; neighbourhood quality; respondent association with trucking industry.
Pedersen, Le Ray, Bendtsen & Kragh (2013/14)	Copenhagen Resurfacing with noise reducing pavement.	B/A study 12 mo. after Not repeated measure	2870 over two areas near roads Response rate 41% Mail surveys	42-74 L_{den} Modelled noise map. Note: wide range of before levels	38-70 L_{den}	Measured 4 dB reduction in source levels Same reduction assumed for all Ps	%HA based on 8, 9 & 10 of ISO (0-10 scale). Mean Annoyance also reported .	**YES** **B&A mean annoyance scores were different (Welch's t-test, p<.001)**	Authors reported logistic regression ERFs for each of before and after conditions (n=2870).The 95% CIs of B & A curves tended to overlap, and authors merged the data to establish the ERF. **Hence change in response to -4dB intervention estimated by the ERF.** B & A ERFs curves are overlapping - largely parallel but with ERF (after) slightly lower than ERF (before). **Response to change estimated by ERF** Slightly lower ERF(A) indicates **excess response.** The authors also report *"…a small tendency to a lower %HA in the 50-60 dB range in the after situation…".*	Merged ERF was higher than Miedema & Oudshoorn (2001) ERF over 60-74 L_{den}	

Figure 4 – Snapshot of part of one group of studies showing an example of how they have been examined

Because of space restrictions, it is not possible to provide the summary observations of each of the

43 transport noise interventions included in this review. However, by way of example of the approach, Figure 4 shows a snapshot of part of a table taken from the analysis of one group of studies. Note the columns in the table recording the observation from the studies showing the answers to the two questions above.

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.

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 (12). 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. SUMMARY

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.

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.

Intervention studies can be difficult to conduct, but a number of those identified in this review were of good quality. However, there is diversity between studies, even within groups, in terms of study designs, methods of analyses, exposure levels and changes in exposure experienced as a result of the interventions. For these reasons, 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. Also there are examples where the effect of the average weighted noise levels was low, but the annoyance was reduced by a chance in traffic composition (e.g. less freight traffic)

The effect of insulation at the façade and noise barriers (Type B) seems according to some (13) more dependent on contextual factors. Some studies suggest that a combination with other measures e.g. more green, improved access to amenities, improved attitude towards the measure by involving people is more effective than the single interventions. This hypothesis is also supported by studies in which changes in noise and its effects was modelled.

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. The following factors came forward from the review: noise sensitivity, distance to the road, availability of a quiet side and window opening behavior. But also the context around the intervention should be considered such as attitude towards policy and the party carrying out the measures. expectations about effectiveness of the intervention and satisfaction with residential area. As stated this is in particular true for type B interventions.

It is appropriate to note the possibility that publication bias may have influenced the findings of this review. We have no evidence of this, but it is reasonable to suggest that 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 changed 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.

Brown and van Kamp (14) discuss the implications of evidence from this review for noise management policy for transport sources.

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REFERENCES

1 Brown, A.L. and van Kamp, I. (2015) A conceptual model of environmental noise interventions and human health effects. Proceedings of Internoise 2015, San Francisco. USA, Paper # 902. Institute of Noise Control Engineering.

2 National Research Council (2002). Estimating the public health benefits of proposed air pollution regulations. National Academy Press.

3 HEI Accountability Working Group (2003). Assessing health impact of air quality regulations: concepts and methods for accountability research. HEI Communication 11, September.

4 van Erp, A.M., Kelly, F.J., Demerjian, K.L., Pope, A. III, and Cohen, A.J. (2012). Progress in research to assess the effectiveness of air quality interventions towards improving public health. Air Quality, Atmosphere and Health 5:217–30.

5 Burns, J., Boogaard, H., Turley R., Pfadenhauer L.M., van Erp, A.M., Rohwer A.C., and Rehfuess, E.

(2014). Interventions to reduce ambient particulate matter air pollution and their effect on health (Protocol). Cochrane Database of Systematic Review 2014, Issue 1. Art. No.: CD010919. DOI: 10.1002/14651858. CD010919.
6 WHO (1999). Guidelines for Community Noise, World Health Organization, Geneva.
7 Schultz, T. J. 1978 ‘‘Synthesis of social surveys on noise annoyance,’’ J.Acoust. Soc. Am. 64, 377–405.
8 Federal Interagency Committee on Noise (FICON) (1992) ‘‘Federal Agency Review of Selected Airport Noise Analysis Issues’’ in Final Report: Airport Noise Assessment Methodologies and Metrics, Washington, D.C
9 Miedema, H. M. E., & Vos, H. (1998). Exposure-response relationship for transportation noise. Journal of Acoustical Society of America, 104, 3432-3445.
10 Miedema, H. M. E., & Oudshoorn, C.G.M. (2001). Annoyance from transportation noise: Relationships with exposure metrics DNL and DENL and their confidence intervals. Environmental Health Perspectives, 109(4), 409-416.
11 European Commission (2002). “Position paper on dose response relationships between transportation noise and annoyance” available at http://ec.europa.eu/environment/noise/pdf/noise_expert_network.pdf .
12 Brown, A.L. and van Kamp, I. (2009) Response to a change in transport noise exposure: a review of evidence of a change effect. Journal of the Acoustical Society of America. 125 (5) 3018-3029.
13 Köhler, J., Ruijsbroek, A. & van Poll, R. (2006). Effectiveness of insulation measures and underlying factors. Proc of Internoise 2006, Honolulu
14 Brown, A.L. and van Kamp, I. (2016) A systematic review of evidence of the effect of transport noise interventions on human health: Implications for future studies and noise management policy. Internoise 2016, Hamburg.