Transport noise interventions and health

A.L. Brown (1), Irene van Kamp (2)

(1) Griffith School of Environment and Science/Cities Research Institute, Griffith University, Brisbane, Australia
(2) National Institute for Public Health and the Environment, Netherlands

ABSTRACT

This paper reports the final outcomes of a systematic review of literature (1980 -2014) of changes in health resulting from transport noise control measures. This was part of the evidence-base for the planned revision of the World Health Organization's Environmental Noise Guidelines for the European Region. While there are many studies of transport noise interventions which report a consequent change in emissions, or change in noise levels near sources, only a limited number have reported resultant health outcomes of receivers. These health outcomes were mostly of annoyance, with a few examining sleep disturbance, cardiovascular effects, and cognitive development in children. The majority of studies included were of road traffic noise; fewer for aircraft noise and rail traffic noise. Because of diversity in the studies, a meta-analysis of association between changes in level and changes in outcome was not feasible. However, it was possible to conclude, though within a limited evidence base, that transport noise interventions do change the health outcomes reported by those who experience the intervention, irrespective of the source type, the outcome, or the intervention type. The minimum magnitude of the change in annoyance outcomes can be predicted from the interventions using a relevant exposure–response function.

1 INTRODUCTION

This paper provides the final summary of a systematic review of transport interventions and their impacts on health that has previously been reported by van Kamp and Brown (2016). The systematic literature review (1980-2014) was of evidence of the effects of transport noise interventions on human health, for roadway, railway, and air traffic sources. Health outcomes considered included changes in sleep disturbance, annoyance, cognitive impairment of children and cardiovascular diseases.

The interventions reviewed were for all types of noise management or control strategies that are found in practice. Five broad categories of transport noise intervention were identified - categorization is necessary as synthesis of evidence regarding outcomes from interventions is only appropriate when the evidence is from studies that belong to the same category of intervention, the same source type, and the same health effect. 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*, which applies where a new source is introduced (say a new by-pass road where there was no roadway previously, or the termination of particular flight paths with the clasure of a runway). A fourth category is *other physical interventions,* such as a quiet side for dwellings, and the fifth is an intervention directed at a change in *behavior*. Van Kamp and Brown (2016) provided more details, and examples of these categories, building a framework within which all types of interventions can be examined.

2 THE STUDY

The 2016 conference paper (van Kamp and Brown, 2016) described in full the conduct of the literature search for this review: the selection criteria for inclusion of studies, and the process of examination of the details of the individual studies. The final outcome of the review has recently been published, and full details are available in Brown and van Kamp (2017). This paper summarize the major findings from the review and the implications of the findings for transport noise policy and management.

3 OVERVIEW OF FINDINGS

Below we provide an overview, across source types, health outcomes, and intervention types, of the results of the studies included in the review. Results included whether or not the intervention resulted in a change in the health

outcome, and the magnitude of the observed change in helath compared to that predicted by an exposure-response function (ERF) appropriate to that study. Table 1 provides this summary overview of the findings for the 43 individual studies included in the review.

Most intervention studies reported in the Table involved road traffic noise (77%), with fewer aircraft noise (16%), and railway noise (7%). The exposure-related interventions were mostly associated with a decrease in environmental 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 refer to both increase and decrease scenarios.

Table 1 shows that, for nearly all entries, and, irrespective of the noise source, health outcome, or intervention type, the intervention led to a change in the aggregate health outcome of those who experienced the intervention (asterisk shown in the YES column). Excluding those studies for which no observation was appropriate (n.a.: 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 noise study reporting no change in health outcomes. The original authors had provided statistically significant tests of this change in 51% of the entries (red asterisks); in a further 37% of entries, this observation was interpreted, by the original authors or as part of the process of this review, from the data, tables, or plots presented in the papers, but without statistical tests (black asterisks).

The Table also provides an overview of the observed magnitude of change in health outcome as a result of the interventions. Seventeen studies of source, path, and new/closed infrastructure interventions for road and aircraft noise sources reported that the minimum magnitude of the change in outcomes (16 of the studies were of change in annoyance outcome; one of change in sleep disturbance outcome) could have been predicted from a relevant exposure–response function (ERF)—and 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. In other words, the reduction in outcome was greater than would be expected based merely on the reduction in noise levels. Brown and van Kamp (2009a) reported that, for road traffic studies, and source intervention changes, the excess-response change-effect tends to be greater (often much greater) than the change in annoyance due to the noise level exposure change itself. Observations of excess response in annoyance were for both road traffic (thirteen studies) and aircraft noise (three studies).

In general, interventions at the source, in the pathway and intervention in infrastructure are effective in reducing annoyance, but 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.

There is also no clear evidence with respect to thresholds regarding changes in health outcomes as a result of interventions. Intervention 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.

When interpreting the results, the quality of evidence for various combinations of source, intervention type, and outcome, needs to be considered. The overall quality of evidence within each of the source/intervention type/outcome groups varied, and was judged to range from high to very low across the different groups.

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.

Table 1. Summary of evidence from the individual studies on the effect of the intervention on health outcomes. Red asterisk indicates statistical significance of finding reported in the original study. Black asterisk indicates finding interpreted by original, or current, authors based on data/tables/plots reported in the original study report. Numbers in parentheses are the numbers of studies. Source: Brown and van Kamp (2017).

	Number of Papers	Evidence [1] That Health Outcome Changed			Observed Magnitude of Change in Health Outcome		
		YES	NO	n.a.	Magnitude *at Least* as Predicted by ERF	Excess [2] Response	n.a.[3]
ROAD TRAFFIC NOISE SOURCES (33)							
Outcome: Annoyance (23)							
A Source Intervention	9	******		**	*******	*******	**
B Path Intervention	6	******			****	** ?	**
C New/Closed Infrastructure	2	**			**	**	
D Other physical	6	*****					
Outcome: Sleep Disturbance (6)							
A Source Intervention	1			*			*
B Path Intervention	2	**					**
C New/Closed Infrastructure	2	**					**
D Other physical	1	*					
Outcome: Cardiovascular Effects (4)							
D Other physical	4	***	*				
AIRCRAFT NOISE SOURCES (7)							
Outcome: Annoyance (4)							
B Path Intervention	1	*					*
C New/Closed Infrastructure	3	***			***	***	
Outcome: Sleep Disturbance (2)							
C New/Closed Infrastructure	2	**			*		*
Outcome: Cognitive Development in Children (1)							
C New/Closed Infrastructure	1	*					*
RAIL NOISE SOURCES (3)							
Outcome: Annoyance (3)							
A Source Intervention	1	*					*
C New/Closed Infrastructure	1			*			*
E Education/Communication	1	*					

[1] Note that the evidence is indirect for Interventions Type D (Other Physical). [2] Excess response occurs where the total difference between the observed before and after outcomes is greater than the magnitude of the change in response estimated from an Exposure Response Function (ERF) for a given change in exposure. [3] n.a. = no change in exposure or not reported. ? = unclear finding.

3.1 Sustainability of the Change in Health Outcomes

Nearly all of the entries in Table 1 were before-and-after studies, with the identification of the magnitude of the change in outcome fixed by the timing of the after-survey following the intervention. This was normally one to twelve months after the intervention, but varied considerably. For some of the interventions involving construction, such as barriers or housing reconfiguration, the gap between before and after studies was much longer: five to six years, and eight to ten years, in some studies.

However, a handful of studies continued to assess participant health outcomes longitudinally beyond the initial after-survey. Four road traffic studies, two aircraft studies and two railway studies resurveyed participants after various intervals: five surveys out to 20 months; six surveys out to three years; 12 months; two years, seven to nine years, etc. While the evidence is meagre and scattered, the consistent finding is that the latter after-surveys showed no difference in outcomes to those surveys immediately following the intervention—with no diminution in the magnitude of the effect, including excess response if present. The exception was that the survey seven to nine years after the intervention did show some attenuation in the excess response observed at the first after-survey.

In summary, while there is little evidence regarding longer-term changes in health outcomes subsequent to the initial change following an intervention, none of it suggests adaptation (adaptation being defined] as movement of the observed excess response, post intervention, towards expected steady-state response levels).

4 IMPLICATIONS FOR NOISE POLICY AND MANAGEMENT

This review has provided a positive answer to an important policy question: d*o environmental noise interventions change health outcomes*? This finding is largely consistent across the transport noise interventions. It shows that many current noise management strategies have a beneficial effect on human health. The caveat is that this evidence is not extensive or well distributed over all transport noise sources, intervention types, or health outcomes.

Another finding is that: *relevant ERFs for annoyance can provide an estimate of the minimum change in human outcomes that can be expected from a given change in exposure as a result of an intervention*. This supports current noise management approaches, as ERFs for annoyance can thus provide a first conservative estimate for the health impact assessment of future interventions. The available evidence is more limited for aircraft noise than for road traffic noise. The evidence for ERFs predicting the minimum change in sleep disturbance is restricted to one aircraft noise intervention study only.

The review demonstrated that there was excess response to the intervention in 14 road traffic noise interventions and three aircraft noise interventions. Excess response occurs where the total difference between the before-outcome and the after-outcomes is greater than the magnitude of the change in response estimated from an ERF for the given change in exposure. The notion of excess response to interventions has been examined by Brown and van Kamp (2009a & b). They found that: '*The evidence of the magnitude, and the persistence over time, of the change effect … and the existence of plausible explanations for it, suggest that it is a real effect and needs to be taken into account in assessing the response of communities in situations where noise levels change. Within the limitations of existing evidence on change, communities that experience an increase in noise exposure are likely to experience greater annoyance than is predicted from existing exposure–response relationships, and communities that experience a decrease in exposure experience greater benefit than predicted. Policy makers need to be informed of these potential change effects, particularly as situations in which noise levels increase as a result of infrastructure changes are always likely to be contentious. To do otherwise would be to deny them important information regarding potential community response in these contexts'*.

5 GUIDANCE FOR FUTURE STUDIES OF INTERVENTIONS

The following are implications arising from this review for further research into the health effects of interventions.

Further studies directly linking environmental noise interventions to health outcomes are required, for all sources of environmental noise, but particularly for aircraft and rail noise sources, and for human health outcomes other than annoyance.

Authorities proposing/funding interventions, whether 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 addendums to, rather than integral components of, the interventions.

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. Intervention studies should use validated, and where possible, harmonised, measures of exposures and outcomes, as well as of moderators and confounders.

We recognize the difficulty in doing so in many intervention studies, but precise specification of the change in exposure for individuals, or subgroups, is desirable. In part to encourage this, we suggest that there are ad-

vantages 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.

Most interventions result in step changes in exposure with expected step changes in human response to this change in exposure. While many intervention studies use a before and after design, there is generally 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.

6 CONCLUSIONS

This systematic review of the literature, 1980–2014, found, overall, that there has been a limited number of transport intervention studies published that report observed changes in health outcomes, or observed changes in peoples' exposures, together with quantitative details on the association between change in exposure and change in human health effects.

The majority of these were for road traffic noise sources; fewer for aircraft noise and rail traffic noise. The principal change in health outcomes assessed was annoyance, with fewer sleep disturbance, cardiovascular effects, and cognitive development in children

We note that there are many studies 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 transport noise interventions, with studies spread across 16 different groupings (grouped by source type, health outcome, and intervention type). Only two of these groupings: source interventions and path interventions for road traffic for the annoyance outcome, consist of more than three studies.

A major difficulty for this review was the diversity between studies, even within those categorised in the same group. This was in terms of study designs method 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. Because of the diversity, a meta-analysis across studies examining the association between changes in level and changes in outcome was not possible.

However, the available evidence did show that transport noise interventions changed the health outcomes reported by those who experience the intervention. This is the case irrespective of the source, the outcome or the intervention type. The minimum magnitude of the change in annoyance outcomes because of the interventions can be predicted using a relevant exposure–response function (ERF). While there is little evidence available with respect to the longitudinal path of health outcomes changes following the initial change as a result of an intervention, there is no evidence to suggest the initial change in response is not sustained over at least several years—that is, there is no adaptation.

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. This evidence was available for studies of road traffic noise sources (and a small number of aircraft noise studies) and largely only for the annoyance outcome.

The available evidence did not allow testing for any differences in change in health outcomes arising from different types of interventions, or for different source types. We also could not make observations regarding thresholds for observable changes in health outcomes, other than that several interventions that reduced noise exposures by −1 to −2 dB did not result in any observed change in health 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. While recognising the difficulty in doing so in many study designs, we suggest that future intervention studies should aim for precise specification of the change in exposure for individuals, or subgroups. There are advantages in following the approach [45-46],

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 analyses.

Policy makers need to be informed of the existence of the change effect associated with interventions, particularly as situations in which noise levels increase as a result of infrastructure changes are always likely to be contentious. To do otherwise would be to deny them important information regarding potential community response to these changes.

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