

SIENA Consortium

Sustainable Infrastructure and Evidence for Noise and Air

EVIDENCE REVIEW FOR EFFECTS OF SOUNDPROOFING ON RESIDENTS' MENTAL WELLBEING AND ALTERNATIVE DESIGNS

VOLUME IV: Non-acoustic Factors

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1. NON-ACOUSTIC FACTORS

1.1. INTRODUCTION AND SCOPE

This section provides a selected general overview of the concept of non-acoustic factors and the impact on humans. Limited illustrative comments are made regarding the findings from the *Review for Effects of Soundproofing on Residents' Mental Wellbeing and Alternative Designs for Indoor Dwellings* commissioned by the United Kingdom Government's Department for Environment, Food and Rural Affairs. Given the wide-ranging transdisciplinary nature and study of non-acoustic factors, it was not within the scope of this project to provide a critical review of the full range of non-acoustic factors found in the systematic review in Volume I of this report.

The topic of non-acoustic factors is rapidly evolving. While there is consensus in the literature regarding the significance and impact of non-acoustic factors, agreement amongst researchers and practitioners regarding causal chains (e.g. moderator versus mediator), attribution of impact (e.g. one-third up to two-thirds) and weighting of indicators (e.g. independent versus dependent variables) varies – sometimes widely, for example, see Gjestland (2018); Gjestland (2019); Guski et al. (2019). Therefore, references in this section are not exhaustive, nor an exposition of the range of views, but representative of selected aspects of the debate that are generally agreed in the literature and relevant to the scope of this report. Selected evidence gaps regarding non-acoustic factors are considered and recommendations for further research are made in the conclusions.

Noise versus sound

For the purposes of this section, the terms *sound* and *noise* are used according to their distinct definitions in the context of environmental noise/sound management. The term *sound* is objective and refers to the definition in physics of the propagation of waves through a material medium (e.g. air, water, other material)¹. *Sound* can also be defined as the 'sensation produced by a[ny] auditory stimulus'² when propagated waves reach the ear and/or body regardless of audibility, see for example Araújo Alves *et al.* (2020); Leventhall (2007); Oohashi *et al.* (2000). The term *noise* is a perceptual construct defined as unwanted and/or harmful sound³. Therefore, *noise* and *sound* have different technical meanings and are not synonymous.

When referring to the human perceptual or affective response, what constitutes *noise* or *pleasant/wanted sound* is subjectively determined by the hearer in context. The subjective response to sound is experienced via psychobiological sensing (Andringa and Lanser, 2013; Denis *et al.*, 2022; Riedel *et al.*, 2021; Stansfeld *et al.*, 2021; van den Bosch *et al.*, 2018; Witchel *et al.*, 2013). This phenomenon refers to the 'interaction between biological systems, cognition and mood' (Birbaumer and Flor, 1998, p.117) and the combined effects. In the case of noise the World Health Organization (WHO) reported in the *Environmental Noise Guidelines for the European Region* (2018, p.1) that environmental noise causes both "psychological and physiological distress". In the case of wanted sounds, i.e. those deemed pleasant by the hearer, research indicating the positive health effects is continually developing (Aletta *et al.*, 2018; Buxton *et al.*, 2021; Payne and Bruce, 2019; Ratcliffe, 2021).

¹ Berg, Richard E.. "sound". Encyclopedia Britannica, 23 June 2023. <https://www.britannica.com/science/sound-physics>. [Accessed 29 July 2023].

² N., Sam M.S., "AUDITORY SENSATION," in PsychologyDictionary.org, 7 April 2013. <https://psychologydictionary.org/auditory-sensation/>. [Accessed 13 October 2023].

³ International Commission on Biological Effects of Noise (ICBEN), <http://www.icben.org>. [Accessed 13 October 2023].

Non-acoustic factors – impact on human perception

Wide scale research and the recognition of the importance of non-acoustic factors spans decades. See for example Bartels *et al.* (2022); Berrien (1946); DeJoy (1984); Farooqi *et al.* (2021); Fielder and Fielder (1975); Fleming (1933); Flindell and Stallen (1999); Hatfield *et al.* (2001); Jeon *et al.* (2011); Job (1988); Job (1996); Laird and Coye (1929); Stansfeld and Matheson (2003); Tarnopolsky *et al.* (1980); Vallet (1987); Vos (2010)

The effects of sound on human health, mental health and wellbeing are complex (Benz *et al.*, 2022; Clark *et al.*, 2020; Schreckenberg *et al.*, 2017; Stansfeld *et al.*, 2021; Van Kamp *et al.*, 2020). The indirect health and mental health impacts of non-acoustic factors via noise induced stress (Babisch, 2003; Münzel *et al.*, 2021; Van Kamp *et al.*, 2020) and the pathway of annoyance are well established (Basner *et al.*, 2013; Gong *et al.*, 2022; Guski *et al.*, 2017).

Sound levels, measured in decibels, have been found to account for only around one-third of the human response to sound in context (Guski, 1999; World Health Organization, 2018). The remaining two-thirds of the human response to sound in context is accounted for by non-acoustic and/or other factors (Bartels *et al.*, 2022). Other factors in this context are generally agreed to be “*unexplained [and] may comprise further not assessed acoustic or non-acoustic factors and/or measurement error*” (Schreckenberg *et al.*, 2022, Abstract). Therefore the importance of the role of non-acoustic/other factors accounting for one-third up to two-thirds of the effects of sound on humans, both positive and negative, is highly significant.

Non-acoustic factors - integrated research, practice and transdisciplinarity

The topic of non-acoustic factors is wide-ranging. The term *transdisciplinary* is intentionally and specifically used in this section to denote the complexity of non-acoustic factors and the range of disciplinary responses that may potentially be required to enact effective solutions in context. Transdisciplinarity is defined here in relation to interdisciplinarity and as distinct from multidisciplinary. Choi and Pak (2006, p.351) describe the concept as:

“Multidisciplinarity draws on knowledge from different disciplines but stays within their boundaries. Interdisciplinarity analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole. Transdisciplinarity integrates the natural, social and health sciences in a humanities context, and transcends their traditional boundaries.”

The terms multi- and transdisciplinary are often, erroneously, used interchangeably. The importance of emphasising the distinction between the two in relation to non-acoustic factors is important. This is because the study of non-acoustic factors encompasses disciplines including public health, mental health, psychology, physiology, sociology, engineering, acoustics, planning, design, environment and sustainability (Lercher, 1996; Lercher *et al.*, 2017). In this way the study of non-acoustic factors can involve the convergence of *multiple* disciplines working in a *transdisciplinary framework* to create *integrative* research and evidence⁴ (separate from the boundaries that remain within multidisciplinary working, as defined above).

⁴ The Difference Between Multidisciplinary, Interdisciplinary, and Convergence Research. 31 August 2020. <https://research.ncsu.edu/rdo/the-difference-between-multidisciplinary-interdisciplinary-and-convergence-research/>. [Accessed 13 October 2023].

The non-acoustic factors framework in Table 1 reflects the *transdisciplinary* nature of non-acoustic factors. Transdisciplinarity is requisite to support integrated research and practice to develop *effective* evidence frameworks and informed practices regarding *salient* non-acoustic factors in context.

Non-acoustic factors – working definition and domains

Recognising the importance of non-acoustic factors, the need for better harmonisation of research and evidence and issues relating to effective transdisciplinarity, work to develop an International Standard Technical Specification⁵ *ISO/AWI TS 16755-1 Acoustics — Non-acoustic factors — Part 1: Definition and conceptual framework*⁶ including an agreed definition of non-acoustic factors is underway via the International Organization for Standardization⁷ (ISO) committee *ISO/TC 43/SC 1/WG 68 - Non-acoustic factors*⁸. This work is being led internationally by the British Standards Institution (BSI) in the EH/1/3 committee on Residential and Industrial Noise⁹. The proposed standard, introduced in November 2022, is in the Working Draft stage and proffers the definition of non-acoustic factors as:

“All factors other than the objective, measured or modelled acoustic parameters which influence the process of perceiving, experiencing and/or understanding an acoustic environment in context, without being part of the causal chain of this process.” (Fenech et al., 2021, p. 4)

N.B. This definition is currently being consulted on via the relevant ISO and BSI committees and may be subject to change. However, it seeks to bring together a range of views on non-acoustic factors into an agreed definition and provides an overarching framework wherein various acoustic and other disciplines can intersect. In preparing the draft text for the proposed International Standard on non-acoustic factors, Fenech *et al.* (2021, p.3, as amended) summarised the views as:

- *“all those factors other than noise level alone which contribute to noise annoyance and similar effects”* (quoting Flindell and Witter, 1999, p.27)
- *“moderating variables, i.e. personal and social aspects of the residents”* (quoting Guski, 1999, p.45)
- *“differences in auditory processing of [various] cues (e.g. spectral-shape sensitivity)”* (quoting Majdak *et al.*, 2014, p.1)
- *“non-DNL factor related determinants”* (quoting Fidell *et al.*, 2011, p.791) (DNL= day-night average sound level in dB)

While definitions of non-acoustic factors vary, each takes account of some/all of the following domains: *personal* (Fields, 1993; Guski, 1999; Job, 1993; Miedema and Vos, 1999; Nguyen *et al.*, 2020; Schreckenber *et al.*, 2022), *social/psychosocial* (Flindell and Stallen, 1999; Maris *et al.*, 2007; Riedel *et al.*, 2021), *tangible* (Jiang *et al.*, 2021; Kim *et al.*, 2013; Kim *et al.*, 2019), and *situational/contextual*

⁵ An ISO Technical Specification (TS) “addresses work still under technical development, or where it is believed that there will be a future, but not immediate, possibility of agreement on an International Standard. A [TS] is published for immediate use, but it also provides a means to obtain feedback”. Retrieved from: <https://www.iso.org/deliverables-all.html#TS>. [Accessed 1 August 2023].

⁶ <https://www.iso.org/standard/84809.html>. [Accessed 5 September 2023].

⁷ <https://www.iso.org/standards.html>. [Accessed 1 August 2023].

⁸ <https://www.iso.org/committee/48474.html>. [Accessed 1 August 2023].

⁹ <https://standardsdevelopment.bsigroup.com/committees/50002169>. [Accessed 1 August 2023].

(Bartels *et al.*, 2015; Basner *et al.*, 2013; Herranz-Pascual *et al.*, 2017; Tarlao *et al.*, 2021). Examples of non-acoustic factors by domain are shown in Table 1.

Non-acoustic factor domains	Examples non-acoustic factors
Personal (e.g. perceptual, psychological, mental and physical health)	Noise sensitivity Perceived control Aural diversity Mental health (e.g. anxiety, depression) Health conditions/medication Soundscape perception (in present time and/or memory)
Tangible (objective)	Design of the physical environment (e.g. insulation, good acoustic design, build quality) Objective acoustic indicators/measurement Location of sensitive dwellings (e.g. bedrooms) Visual modifiers
Psychosocial (e.g. agreed within an affected community)	Shared sense of: <ul style="list-style-type: none"> • community benefit/disbenefit • agency to enact change/be heard • effective engagement methods/processes • fairness – sharing in net gains versus impact/sacrifice Inclusive and participatory design Trust in decision makers
Situational (as experienced in context)	Context – lived experience Temporality Expectations relative to use case Accessibility requirements Local environmental quality

Table 1. Examples of non-acoustic factors by domain adapted from Fenech et al. (2021, p.7) and the draft International Standard ISO/AWI TS 16755-1 Acoustics — Non-acoustic factors — Part 1: Definition and conceptual framework in which categories of non-acoustic factors are presented based on an initial general review of the literature. The need for a more comprehensive review of non-acoustic factors is acknowledged. It is also noted that some non-acoustic factors may present in multiple domains and/or can change over time depending on the context and use case in which they occur. For example noise sensitivity may be temporarily induced by an objective medical event/medication, and/or may be a longer term psychological condition (Kliuchko et al., 2016; Shepherd et al., 2015).

Non-acoustic factors standardization - soundscape and traditional acoustics

According to Fenech *et al.* (2021, pp.2-3, emphasis added):

“In recent years there has also been a growing interest in the soundscape approach (in line with the development of the ISO 12913 Soundscape Standards series) with an emphasis on how sound in an environment is experienced by a person and/or people in context. According to ISO 12913-1:2014 assessing soundscape in context includes: “the interrelationships between person and activity and place, in space and time... [and] context may influence soundscape through (1) the auditory sensation, (2) the interpretation of the auditory sensation, and (3) the responses to the acoustic environment.” (quoting ISO, 2014, p.2). Therefore identifying, measuring and assessing non-acoustic factors is central to measuring and assessing soundscape in accordance with the soundscape standards. Despite the key role that non-acoustic factors play in both the ‘traditional’ health protection (noise control) and health promotion/improvement (soundscape enhancement) approaches, to date, there is no standardised specification for the assessment of non-acoustic factors in social surveys.”

As a practical response to the approach of traditional noise management, control and abatement practice/research, the standard on non-acoustic factors (*ISO/AWI TS 16755-1 Acoustics — Non-acoustic factors — Part 1: Definition and conceptual framework*) was proposed, as noted. Soundscape standards encompass non-acoustic factors within the definition of “context”. Therein “context” is defined as including non-acoustic factors: for example *situational, temporal, personal, physiological, psychological and psychosocial factors* (ISO, 2014, pp.1-2). However, conventional noise standards, practices, policies and the majority of literature on the effects of noise may define non-acoustic factors separately from context and/or sound source measurements [e.g. see World Health Organization (2018, p.14)] where non-acoustic factors are defined separately to the exposure-response effects directly related to sound levels.

Therefore, the aim of the non-acoustic factors standard is “to achieve consensus on a clear definition for the term “non-acoustic factors”” (Fenech *et al.*, 2021, p.3) and its usage and application in *both* soundscape practice and in conventional acoustics. It is accepted that the definition may pragmatically be defined differently within standardised soundscape practices versus conventional noise research and practices. Equally an agreed definition of non-acoustic factors may change over time, given the relative newness of soundscape standardisation as well as emerging research and evidence on non-acoustic factors, mental health and wellbeing, and noise and health.

While it is outside the scope of this paper to explore the debates on the nature of non-acoustic factors, detailed discussions are ongoing amongst noise and soundscape experts and the topic remains under review. Discussions include, for example, whether non-acoustic factors are dependent or can be independent of context (N.B. as there is not currently a single agreed definition of “context” for both noise and soundscape standards); are moderators, mediators or confounders; the role of weighting and significance of non-acoustic factors in relation to perception and health effects.

Non-acoustic factors in policy and guidance

The WHO (2018, p.103) emphasises the importance of non-acoustic factors and the need for an improved evidence base, calling for:

“Future intervention studies [to] use validated and, where possible, harmonized measures of exposure and outcome, as well as of moderators and confounders. [...] [and] measures of moderators and confounders, including repeated measurements of situational and personal variables such as activity interference, potential confounders such as noise sensitivity, coping strategies and a range of other attitudinal variables.”

Policy, law, guidance and standards regarding environmental noise have traditionally focused predominantly on noise abatement and reduction to reduce the negative health effects from unwanted sound. This is the case in the UK and internationally. Examples in the UK and Europe include: the Environmental Noise Directive (European Union, 2002) and the Environmental Noise (England) Regulations 2006 (Department for Environment Food and Rural Affairs, 2006).

Increasingly, however, these instruments are being updated and developed to focus more on sound, taking account of both positive and restorative (e.g. tranquility, soundscape, sound quality, positive sounds), as well as negative (noise) effects. UK examples include in part: BS 4142:2014+A1:2019 - Methods for rating and assessing industrial and commercial sound (British Standards Institution, 2019); ProPG: Planning & Noise – New Residential Development – Supplementary Document 2 Good Acoustic Design (Association of Noise Consultants et al., 2017); the Noise Policy Statement for England (Department for Environment Food and Rural Affairs, 2010); the Noise Policy Statement for Northern Ireland (Department of the Environment, 2014); the Strategic Planning Policy Statement for Northern Ireland (Department of the Environment, 2015); Planning Advice Note, PAN 1/2011, Planning and Noise (Scottish Government, 2015); Planning for Place – Local Government Improvement in Scotland (Improvement Service, 2023); the Noise and Soundscape Action Plan for Wales 2018-2023¹⁰ (Welsh Government, 2018); Technical Advice Note 11: Air Quality, Noise and Soundscape¹¹ (Welsh Government, 2022); The Environment (Air Quality and Soundscapes) (Wales) Bill 2023¹² (Welsh Government, 2023).

Non-acoustic factors – general commentary on findings from the systematic review

This overview presents selected commentary following a general review of the evidence of non-acoustic factors from the systematic review of the literature for the years 2019-2023 in ‘Volume I - Systematic Review’ (Clark, C., Willis, K., Marcus, E.) of this report.

All the studies in the systematic review (see Table 3), were found to include non-acoustic factors. The evidence from the studies (n=59) show effects of non-acoustic factors across a range of impacts, including those related to: *mental health* (e.g. depression, anxiety, coping ability); *wellbeing* (e.g. physical and mental distress, sense of safety, restoration, vulnerability); *quality of life* (e.g. impacts on daily activities including working/studying from home, conflicts with neighbours); *annoyance* (including noise sensitivity, perceived loudness and cumulative effects of noise over time); and *sleep* (e.g. the impact of non-acoustic factors on quality of sleep, for example feeling safe at night in relation to the sound environment). Non-acoustic factors in the included studies from the systematic review

¹⁰ An open consultation on Welsh Government policies concerning the airborne sound environment was recently conducted (and ended on 2 October 2023). A summary of the evidence, Welsh Government current policies and priorities for the next five years are set out in the draft *Noise and Soundscape Plan 2023-2028*. Once adopted, this will serve as Welsh Government national strategy on soundscapes until its next review and update, which is expected to occur in 2028. <https://www.gov.wales/noise-and-soundscape-plan-wales-2023-2028.html>. [Accessed 13 October 2023].

¹¹ This document formed part of a Welsh Government consultation on revised planning guidance in relation to air quality, noise and soundscape. The consultation ended on 20 January 2023, the outcome of which will be published in due course. <https://www.gov.wales/revised-planning-guidance-relation-air-quality-noise-and-soundscape>. [Accessed 13 October 2023].

¹² In the United Kingdom, a Bill is a draft law. At the time of writing this Bill is currently at Stage 3 in the Welsh Parliament. <https://business.senedd.wales/mglIssueHistoryHome.aspx?IId=40984>. [Accessed 16 October 2023].

are demonstrated across the four dimensions of non-acoustic factors noted in Table 1. Examples of non-acoustic factors from the systematic review within these dimensions are shown in Table 2.

Non-acoustic factor domains	Examples of non-acoustic factors from the included studies in the systematic review in Volume I of this report
Personal (e.g. perceptual, psychological, mental and physical health)	annoyance, stress, coping ability, perceived control, self-reported health, noise sensitivity, demographics, physical and mental health, different abilities, perception of sounds and the ambient sound environment, audible safety, memory
Tangible (objective)	housing typology, insulation, construction, building services, accessibility, access to good quality green space, urban morphology, temporality, quiet sides, placement of sensitive areas, views/visual features, objective acoustic features and/or level/characteristics
Psychosocial (e.g. agreed within the affected community)	quality of relationship with neighbours, community cohesion, attitude towards the noise source, accepted cultural norms, mediated solutions, effective engagement, placemaking, culture and amenity
Situational (as experienced in context)	interaction between all <i>contextually salient</i> non-acoustic factors in relation to expectations, preferences, use cases and experienced reality both actual and perceived, good acoustic design, suitable insulation, heating and ventilation

Table 2. Examples of non-acoustic factors from the included studies in 'Volume I - Systematic Review' (Clark, C., Willis, K., Marcus, E.) of this report (see Table 3 for a list of the studies). The non-acoustic factors are shown within the framework adapted from Fenech et al. (2021, p.7) and the draft International Standard ISO/AWI TS 16755-1 Acoustics — Non-acoustic factors — Part 1: Definition and conceptual framework.

The included studies in the systematic review explore non-acoustic factors in a variety of contexts through a matrix of qualitative, quantitative and mixed methods approaches. The categories of non-acoustic factors represented in the systematic review align with the corpus of research on the topic over time, as discussed. In this regard, the findings for *general adult populations, sense of wellbeing and soundscape* are as expected. In the case of newer/novel use cases, in the *studies associated with COVID-19, working from home (WFH), elderly and dementia populations* (see Table 3), the non-acoustic factors found are also as expected for the use cases – e.g. ability to work and/or study effectively, and restoration. For example, similar issues noted in the studies regarding privacy, sound levels, traffic noise, anthropomorphic activity and ability to concentrate have been shown in research for these use cases in non-residential settings [e.g. offices and learning environments – see for example Banbury and Berry (2005); de Lima Andrade et al. (2021); Dohmen et al. (2022)].

While the findings overall are as expected, the evidence serves to support and extend existing research on non-acoustics factors in specific use cases (e.g. health care, home environments) and for specific populations (e.g. WFH, elderly, those with dementia). The results add value to emergent epistemological approaches that are being trialled through basic and empirical research.

A view of the findings can be taken that they show a vibrant, creative and innovative research community and underscore the reality of the impact of non-acoustic factors. Equally, the findings illustrate the need for agreed research paradigms for non-acoustic factors to widen the effectiveness, generalisability and applicability of the evidence beyond novel use cases. As noted, within the corpus of studies included in the systematic review all included non-acoustic factors. However, several quality issues were identified including lack of methodological rigour and bias; and lack of harmonisation of data collection, analysis and reporting across studies. A summary of the evaluation of the included studies taken from the systematic review is shown in Table 3.

Relationship	Studies included in the Systematic Review for this report 'Volume I - Systematic Review' (Clark, C., Willis, K., Marcus, E.) (n=59)	GRADE Evaluation	GRADE-CERQual Evaluation
Surveys of residential settings and effects on wellbeing and perceptions: <i>general adult populations</i>	Eighteen studies (Amiryar and Asano, 2022; Argalasova <i>et al.</i> , 2022; Benz <i>et al.</i> , 2021; Dance and Gomez-Agustina, 2021; Gilani and Mir, 2021; Hasegawa and Lau, 2022; Hasegawa <i>et al.</i> , 2022; Kou <i>et al.</i> , 2021; Lee <i>et al.</i> , 2020; Mohamed and Dokmeci Yorukoglu, 2020; Park and Lee, 2019a; Park and Lee, 2019b; Pedersen <i>et al.</i> , 2021; Qu and Tsuchiya, 2021; Santurtún <i>et al.</i> , 2022; Walsh <i>et al.</i> , 2021; Wang and Norbäck, 2021; Warner <i>et al.</i> , 2022; Xie <i>et al.</i> , 2021). These studies represented a range of geographies and used quantitative, qualitative, and mixed-method approaches. The studies were cross-sectional.	Very low quality	Very low confidence
Surveys of residential settings and effects on wellbeing and perceptions: <i>elderly populations</i>	Four studies (Cui <i>et al.</i> , 2021; Mu <i>et al.</i> , 2021; Wu <i>et al.</i> , 2022; Xie <i>et al.</i> , 2020). All the studies were conducted in China. Some studies used the ISO soundscape approach in care homes. Some studies used standardised health outcomes to assess links of sound and noise on depression and loneliness.	Very low quality	Very low confidence
Surveys of residential settings and effects on wellbeing and perceptions: <i>Working from Home (WFH) populations</i>	Seven studies (Andargie <i>et al.</i> , 2021; Boegheim <i>et al.</i> , 2022; Natomi <i>et al.</i> , 2022; Torresin <i>et al.</i> , 2022a; Torresin <i>et al.</i> , 2021; Torresin <i>et al.</i> , 2022b; Torresin <i>et al.</i> , 2022c). These studies examined sound and noise, wellbeing, stress, comfort, and perceived productivity in WFH populations. Some of these studies were conducted to examine how sound and noise had changed at home during COVID-19.	Low quality	Very low confidence

Effects and changes to sound and noise associated with COVID-19	Nine studies (Andargie <i>et al.</i> , 2021; Bower <i>et al.</i> , 2023; Caniato <i>et al.</i> , 2021; Dzhambov <i>et al.</i> , 2021; Mimani and Nama, 2022; Torresin <i>et al.</i> , 2022a; Torresin <i>et al.</i> , 2021; Torresin <i>et al.</i> , 2022b; Torresin <i>et al.</i> , 2022c). The studies examined (in varying degrees) effects including annoyance, anxiety, depression and loneliness regarding sound and noise in residential settings on wellbeing and perceptions in relation to COVID-19.	Moderate quality	Very low confidence
Experimental studies of residential settings and effects on wellbeing	Sixteen studies (Asakura and Hashimoto, 2020; Chung <i>et al.</i> , 2019; Frescura and Lee, 2021; Frescura and Lee, 2022; Frescura <i>et al.</i> , 2022; Jeon and Jo, 2019; Jeon <i>et al.</i> , 2019; Jeong, 2021; Jo and Jeon, 2019; Lu <i>et al.</i> , 2023; Mu <i>et al.</i> , 2023; Torresin <i>et al.</i> , 2020a; Torresin <i>et al.</i> , 2020b; Wang <i>et al.</i> , 2022; Yang <i>et al.</i> , 2019; Yang and Moon, 2019). The studies examined a range of different residential features, and some considered how the link between sound, noise and wellbeing might be influenced by other environmental features such as temperature and visual factors.	Very low quality	N/A
Residential care homes & dementia	Six studies (De Pessemier <i>et al.</i> , 2023; Graham, 2019; Graham, 2020; Houben <i>et al.</i> , 2020; Kosters <i>et al.</i> , 2023; Kosters <i>et al.</i> , 2022). These studies evaluated soundscape interventions on social relations and symptoms of dementia in care homes.	Moderate quality	Very low confidence

Table 3. Summary of the evaluation of the included studies for this report taken from Tables 27 and 28 in 'Volume 1 - Systematic Review' (Clark, C., Willis, K., Marcus, E.). The studies were evaluated via GRADE13 and GRADE-CERQual14. All of the studies included non-acoustic factors.

When considered in the context of the GRADE and GRADE-CERQual evaluation criteria, the results from the systematic review shown in Table 3 (and Volume 1 of this report) serve to highlight the emergent nature of research on non-acoustic factors and the challenges of transdisciplinarity. This can be attributed in part to the methods of data collection, measurement and assessment of non-acoustic factors which is currently non-standardised both across and within disciplines. For example, where acoustic standards are applied in the reviewed studies, e.g. the soundscape standards (ISO 12913

¹³ GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) "is a transparent framework for developing and presenting summaries of evidence" <https://bestpractice.bmj.com/info/toolkit/learn-ebm/what-is-grade/> [accessed 7 September 2023].

¹⁴ GRADE-CERQual is a framework "for assessing how much confidence to place in the findings of a qualitative evidence synthesis" <https://www.cerqual.org/what-is-the-grade-cerqual-approach2/> [accessed 7 September 2023].

series) or the noise annoyance standard (ISO/TS 15666:2021), they are not always done consistently or within a clear methodological framework. In some cases, where these standards were applied within the mixed methods studies in the systematic review, they utilised analysis frameworks from various non-acoustic fields (e.g. psychology, biology, a range of other social sciences). While individual studies may be of high quality when assessed within and against discrete peer groups - wherein the relative quality of novel research designs and emergent work may be more readily determined – the results of the systematic review have shown that studies demonstrating clear reporting standards aligned to conventional evaluation frameworks, such as those used in this report, are limited.

Thus, when a corpus of ‘emergent’ work - where little or no precedent exists and/or incorporating multiple disciplines and non-harmonised methods - is assessed in a standardised framework the results of the GRADE and GRADE-CERQual evaluations are not unexpected. Therefore, an important finding from the systematic review is the lack of an agreed consensus on the data collection, assessment and impact of non-acoustic factors within the context of specific indoor sound environments and, by extension, the reliability, usability and potential validity of the findings outwith the studied contexts and use cases. As noted, this finding is as expected given the complexities of researching non-acoustic factors.

2. CONCLUSION

This section presented an overview of non-acoustic factors and a general commentary on the findings from the systematic review for the *Review for Effects of Soundproofing on Residents' Mental Wellbeing and Alternative Designs for Indoor Dwellings* commissioned by the United Kingdom Government's Department for Environment, Food and Rural Affairs.

All of the studies in the systematic review included non-acoustic factors. The findings overall for non-acoustic factors were as expected and in line with previous literature on the topic. An overview of the findings summarised in Table 2 emphasises the outsized impact of non-acoustic factors on the human perception of sound and the impacts on mental and physical health, wellbeing and quality of life.

While the findings show that non-acoustic factors play a significant role in the experience of indoor sound environments, as expected, the emergent nature of the research, both generally and in relation to non-acoustic factors is not standardised (e.g. for data collection, analysis, reporting and quality/rigour frameworks). This is reflected in the evaluation results from the systematic review (see Table 3 and Volume I of this report) where the evaluation ratings were for GRADE: Very Low to Moderate quality, and/or for GRADE-CERQual: Very Low confidence.

Overall, the findings highlight the critical importance of designing/adapting/renovating/upgrading indoor sound environments for use cases aligned to public, community and individual health and wellbeing outcomes in relation to *combined indoor and outdoor* local environmental quality.

Given the complex, multi-factorial nature of non-acoustic factors transdisciplinary basic, empirical and applied research is needed in the UK to build upon the existing corpus of international inter- and multi-disciplinary research. The need for an integrated transdisciplinary approach is identified as a way forward to agree frameworks for harmonised data collection and assessment across multiple disciplines (e.g. acoustics, medicine, psychology, physiology, architecture, human geography) and applications (e.g. environmental quality, placemaking, biodiversity, planning, building services).

It is recommended that future research and evidence reviews include, within the project scope, critical reviews of non-acoustic factors and alternative metrics in addition to traditional acoustic metrics.

3. ABOUT THE AUTHOR

Lisa Lavia FRSA is managing director of UK NGO the Noise Abatement Society.

She is a communications and engagement specialist with over 30 years' experience in the commercial and not-for-profit sectors. Lisa holds an MBA and is conducting doctoral research on soundscape, planning and wellbeing at Heriot Watt University in the UK.

Lisa actively participates in the development of international and British standards on soundscape and non-acoustic factors via the International Organization for Standardization (ISO) and British Standards Institution (BSI). She is a member of ISO/TC 43/SC 1/WG 54 – Perceptual Assessment of Soundscape Quality and ISO/TC 43/SC 1/WG 68 – Non-acoustic Factors. Her work encourages the practical implementation in policy, design and planning of the human contextual response to sound through campaigning, outreach and applied research. Her particular focus is on the mental health effects of sound and developing integrative evidence frameworks to measure and assess impact.

Lisa is a member of the Institute of Acoustics, the Royal Society for the Encouragement of Arts, Manufactures and Commerce (the RSA), and the Acoustical Society of America.

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