INCLUSIVE ACOUSTIC DESIGN FOR MAINSTREAM SCHOOLS: AN EVIDENCE BASED APPROACH

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ABSTRACT

A review of the evidence base was undertaken to answer the following questions on behalf of the Department for Education in England:

• What are the differing listening needs for students with different types of special hearing and communication needs (SHCN)?

• How can we quantify the listening disadvantage for different types of listening needs, including SHCN, English as an Additional Language, Early Years and other emerging listening needs?

Over 250 studies were considered to establish the prevalence of each listening need in mainstream schools in England and Wales, and the typical listening disadvantage associated with each need in both quiet and active classrooms. Suitable reasonably adjusted acoustic conditions in mainstream schools were established for each need, together with provision of listening aids and other design measures, in order to support access to listening. A theoretical model of classroom acoustic response was used to check the validity of the proposals. A summary of the findings is presented in this paper along with a comparison of the reasonably adjusted condition with those documented in national standards and guidelines across the world. A user-centric framework to consider acoustic performance requirements is proposed.

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1. INTRODUCTION

This paper summarises findings from a study funded by the Department for Education to investigate listening needs for students in mainstream schools, towards achieving a more inclusive acoustic design approach to the listening environment. Currently all new schools in England and Wales are subject to the acoustic performance standards in BB93[1] in order to comply with the Building Regulations [2]. Enhanced acoustic criteria (30 dB $L_{Aeq,30mins}$; 0.4 s $T_{125\text{-}4kHz}$) are stipulated for *"Teaching spaces intended specifically for children with Special Hearing and Communication Needs (SHCN)"*. This standard is typically applied to small SEN rooms or special units within mainstream schools. School Premises Regulations supporting guidance[3] states that *"where pupils with special needs are taught in mainstream schools, the acoustics of the spaces where they are taught may need to be enhanced to the same standards as those special units*", and "*provision will usually be required to teach these pupils in smaller groups so that noise from other pupils is lower and the distance between teacher and pupil is minimised"*. However in practice this is often impractical and inappropriate to achieve in the larger mainstream classrooms, due to the follow constraints:

a) A shift to a 'Quality First Teaching' approach, focusing on inclusive, differentiated, whole class teaching, leads to children with SEN often remaining in the classroom to receive the majority of their learning direct from their

teacher, reducing outside interventions taking place in SEN group rooms. Teaching pupils in small group rooms or units to access the majority of their learning is generally not considered to be an inclusive teaching approach.
b) Given the current prevalence, schools need to anticipate the presence of children with SHCN in every classroom (see below).
c) Large mainstream classrooms with up to 25-30+ children present generate significant activity noise (generating around 40 dBA even when engaged in a quiet task such as silent reading or critical listening during whole class teaching [4]). This obviates the need to design to ambient noise levels of 30 dBA.
d) A minimum reverberation time of around 0.45-0.5 seconds to promote good early reflections in the classroom is needed to support teachers voice reaching typical communication distances of up to 6 m in larger mainstream classrooms and avoiding vocal strain [4].
e) Trends for exposed concrete soffits, for thermal cooling and limited available wall area mean provision of sound absorption (particularly effective low frequency absorbers) is limited.
f) Taller classrooms (>3.2m) are often desirable to promote daylighting, IAQ, thermal comfort, and create light and airy spaces with cross ventilation. Resulting larger volume spaces make it more difficult to control reverberation time.
g) Natural ventilation remains a priority, resulting in indoor ambient noise levels of 40 to 45 dBA in some new and refurbished classrooms.

In accordance with The Equality Act 2010 [5], schools are required to make ‘reasonable adjustments’ to put children with disabilities on a more level footing. The Output Specification [6] requires that *‘People with disabilities, including those with a hearing impairment, must not be placed at a disadvantage by the design of the Building’*.

In order to address the above issues and ultimately develop acoustic design criteria for a more inclusive listening environment, it is firstly important to understand who may be disadvantaged by the acoustic design of the building, and quantify the disadvantage faced by children with different needs. This has been carried out by examining the literature on speech perception studies for each need and school census statistics.

2. PREVALENCE OF SHCN IN MAINSTREAM

Figure 1 illustrates the BB93 2015 definition for SHCN.

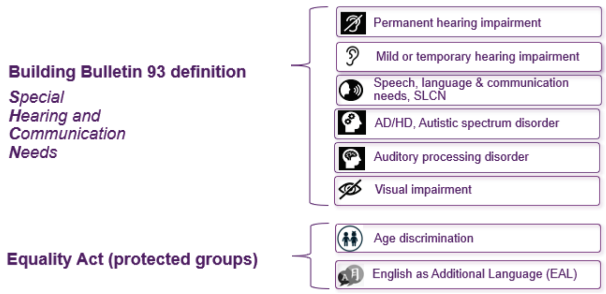

Figure 1. Definition for SHCN (Image © Anderson Acoustics)

BB93 states “In order to fulfil their duties under the Equality Act 2010, school client bodies should anticipate the needs of deaf and other disabled children as current and potential future users of the school” [1]. Since the last update to BB93 in 2015, other emerging needs which may be disadvantaged by the acoustic design of the classroom include children with dyslexia (debated, see below), developmental language delay and specific language impairment, and students with social emotional and mental health needs.
The Equality Act also covers age discrimination (for example young children) and children with English as an additional (EAL). Both of these groups may be disadvantaged by poor acoustic conditions in the classroom and may also be considered as having SHCN. The above needs may be captured under the umbrella term ‘Aurally Diverse’ listeners.
An assessment of the prevalence of SHCN in mainstream schools was undertaken following detailed analysis of updated 2021 DfE Statistics [7,8]. Results are illustrated in Figure 2. Results indicate that the 2021 prevalence of SHCN is 8% overall (this is up from 6% in 2018 [4]), plus 3% SEMH. Results differ by sector, with needs highest in nursery schools. The most prevalent type of SHCN is Speech Language and Communication Needs (SLCN), followed by ASD and SLD (includes AD/HD and dyslexia).
Prevalence of SLCN decreases with age, whereas SEMH increases with age, being most prevalent at secondary school. Prevalence for permanent hearing impairment in mainstream schools is very low at 0.3% (equivalent to around one child per 2FE primary school). Estimates have also been added for mild and temporary hearing loss (15% [4]), which mainly affects the nursery and primary sectors.

The results indicate that on average every classroom needs to anticipate at least two children with permanent SHCN per mainstream classroom (needs to be anticipated, and up to 7-8 if temporary hearing loss is included. Prevalence in individual schools may vary due to some mainstream schools specializing in certain needs with dedicated units.

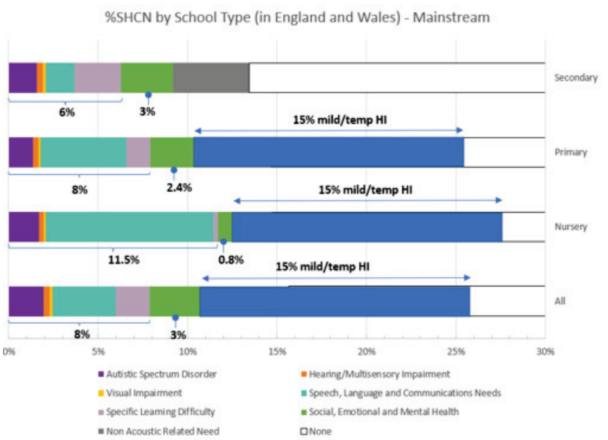

Figure 2. %SHCN by School Type.

(Image © Anderson Acoustics)

Whilst the attainment gap for hearing impaired students has begun to slowly reduce since 2015, it is reported that deaf children continue to underachieve significantly [4]. Yet the learning gap for HI is significantly smaller than that reported for other forms of SHCN. National progress scores for English and Maths reveal a gap of up to 10% for hearing impaired children, compared to 25% for ASD and 30% for SLCN [9], which are both the most prevalent forms of SEN in mainstream schools.

3. SHCN AND LISTENING DISADVANTAGE

A review of the experimental speech perception studies which investigated the effects of reverberation time and/or noise on the subjective word/sentence recognition scores of children with SHCN and their typically developing peers was undertaken. The review focused on realistic acoustic conditions in the classroom, during quiet (+15 dB SNR) to reflect teacher-to-student speech perception in critical listening scenarios, and in noisy classroom babble (nominally 0 dB SNR), to represent teacher-to-student speech perception in the active classroom.

In a novel approach which directly addresses the DfE's inclusion policy, the listening disadvantage has been quantified, that is, the difference in % speech perception scores between the 'impaired' group and non-impaired group for each type of SHCN. This reveals the inherent % listening gap of the impaired groups (under ideal acoustic conditions of 15-20 dB SNR and 0.3-0.5 s RT), and the additional % listening gap caused by non-ideal conditions. This approach also helps to reveal consistencies between studies, as systematic variations between different study methods are reduced. Where several different studies have informed a particular need, results are often remarkably consistent, despite variations between studies in the presentation of the speech testing material amongst other methodologies.

A number of other impacts were investigated in the study which went beyond the scope of speech perception scores, such as auditory processing deficit, listening effort, response time sensory integration/processing, sensitivity to noise, wellbeing and emotional development, working memory, academic achievement, stress response, task performance, attention, distress, anxiety, distraction, fatigue and social interaction, however the results are not detailed in this paper.

Findings are summarised in Table 1. Where % disadvantage is not quantified, the increase in SNR required to match control group peers is presented.

As expected, the inherent listening gap (in quiet, ideal conditions) is greatest for children with severe-to-profound hearing loss, at 9-12%. Whilst the inherent gap for minimal to mild hearing loss is minor (4-5%), increased response time and hence additional listening effort also presents a disadvantage for this need. For primary aged children with mild-to-moderate hearing loss, the inherent listening gap for sentence material is 6-7% in quiet (+20 dB SNR). This is comparable to the 5-6% gap for children with Developmental Language Delay and Specific Language Impairment (considered here also as SLCN, although SLCN is broader than these specific needs).

The listening disadvantage in quiet, ideal conditions (with regards to speech perception) is minor or negligible for other non-sensory educational needs such as ASD (High functioning children with Aspergers or Autism needed +2 to +3.5 dB higher SNR in quiet than control group, a minor but significant difference), APD, AD/HD, Dyslexia (The effect of Speech Perception in Noise on students with Dyslexia is debated due to likelihood of comorbid language disorders (DLD, SLI)). However, in an active classroom (0 dB SNR), the listening disadvantage becomes significant for these needs, in some cases (for example Specific Language Impairment and AD/HD), approaching that for mild hearing impairment. The disadvantage for children severe-profound HI listening in an active classroom (0 dB SNR) is severe at 46-66%.

Table 1. Listening disadvantage by SHCN need

Type of SHCN	Broad Area of SEN	Listening Disadvantage, %	
		Inherent Gap Ideal conditions (15-20 dB SNR; 0.3-0.5s RT)	In active classroom (0 dB SNR)
OME	N/A	Not quantified	Not quantified
$HI_{min-mild}$	N/A	4-5% [10,11]	18-26% [10,11,12]
$HI_{mild-mod}$	Sensory	6-7% [13, 14,15]	19-35% [13,14]
HI_{S-P}	Sensory	9-12% [13, 16,17]	46-66% [13, 16, 18]
VI	Sensory	Not quantified	Not quantified
ASD	COINS	% not quantified, +2-3.5 dB [38][2]	10% [19]
APD	COINS	0% [20] or +7 dB [37]	Not quantified
SLCN	COINS	See DLD, SLI	See DLD, SLI
AD/HD	SEMH	0% [22,23]	34% [22]
SEMH	SEMH	Not quantified	Not quantified
Dyslexia[1]	SpLD	0% [21, 24, 25, 26][1]	9-11% [21][1]
DLD, SLI	SpLD	5-6% (SLI, DLD) [17, 21]	22-25% (SLI) [21]
EAL	N/A	1-4% [27, 28]	8-12% [27, 29, 30, 31]

OME: Otitis Media with Effusion (Temporary, Conductive hearing Loss)
$HI_{min-mild}$: Minimal-to-Mild Hearing Impairment
$HI_{mild-moderate}$: Mild-to-Moderate Hearing Impairment
HI_{S-P}: Severe-to-Profound Hearing Impairment
VI: Visual Impairment
ASD: Autisitic Spectrum Disorder incl. Autism and Aspergers Syndrome
APD: Auditory Processing Disorder
SLCN: Speech Language and Communication Needs
AD/HD: Attention Deficit Hyperactivity Disorders including ADD
SEMH: Social Emotional and Mental Health including Anxiety, Depression and Attachment Disorder
DLD: Developmental Language Delay, also known as Specific language impairment SLI, Language Impairment, Language learning difficulties and Verbal dyspraxia.
EAL: English as an Additional Language
COIN: Communication and Interaction Needs
SpLD: Specific Learning Difficulty

It is important to note that the listening disadvantage analysis in Table 1 is based on differences in speech perception scores and does not identify other related impacts of noise for specific non sensory needs, such as hyperacusis and high sensitivity to noise (evidenced for children and young adults with ASD [32-34]) and SEMH needs [35,36], auditory processing differences, attention, working memory, wellbeing and academic progress.
Research is needed to understand the listening disadvantage for children with SEMH and the specific impact of noise on children with SEMH (whilst controlling for other co-morbidities such as ASD and SLCN). However sensory processing disorder, including noise sensitivity/auditory filtering, has been linked to children with anxiety [35] and attachment disorder [39, 40] depression in young adults [36].

3.1 English as an additional language (EAL)

Although EAL is not listed specifically under the BB93 SHCN definition, BB93 does state in relation to the Equality Act that those protected from discrimination includes those where English is not the first language and clarity of speech is particularly important to assist comprehension. The proportion of children with EAL in state funded mainstream schools was as follows: Nursery Schools: 29%; Primary Schools: 21%; Secondary Schools: 17%.
A pupil is recorded to have EAL if they are exposed to a language at home that is known or believed to be other than English. This is not a measure of English language proficiency. Impact on educational achievement for EAL learners lies mainly in the Early Years Sector and throughout KS1 when many are new to English or still acquiring proficiency (and only 30% of EAL pupils in Reception are competent or fluent [40]. The DfE SEND Code of Practice 2015 [50] states that *"Identifying and assessing SEN for children or young people whose first language is not English requires particular care. Schools should look carefully … to establish whether lack of progress is due to limitations in their command of English or if it arises from SEN or a disability. Difficulties related solely to limitations in English as an additional language are not SEN"*.
Nevertheless, speech in noise perception for EAL children of all ages is linked to age of language acquisition, and lower phonological coding has been found where the additional language is acquired after age 4-6. Whilst the listening disadvantage for speech perception scores for children is small under quiet conditions at 1-4% [27, 28], in an active classroom (nominally 0 dB SNR), the listening gap disadvantage increases to 8-12% [27, 29, 30, 31].
A very similar disadvantage of 8-11% was reported for truly bilingual adult listeners even though they demonstrated equal proficiency in both languages and acquired their language prior to 6 years old [42]. Furthermore, EAL listeners have longer reaction times and pupillometry responses on tasks (symptomatic of extra listening effort), even when listening in quiet [43]. The greater listening effort required for EAL listeners may result in increased fatigue and a reduced ability to successfully perform multiple tasks simultaneously.

The evidence base demonstrates that, even where language proficiency is high and children are truly bilingual, these children may still be considered to have a special hearing and communication need, owing to the extra listening effort expended even in quiet conditions, and the reduced speech perception in noisy conditions.

3.2 Early Years

Listening disadvantages by age of pupils are summarised in Table 2. It can be seen that early years and KS1 are more affected than KS2 in both quiet and active classroom conditions (note different studies and experimental conditions between Early Years and Primary, results should be considered with caution).

Table 2 Listening disadvantage by pupil age

Stage	Listening Disadvantage, %	
	Inherent Gap Ideal conditions (10-15 dB SNR)	In active classroom (0 dB SNR)
Early Years	2.5% [44] -5% [45]	10% [44] – 25%[45]
Primary KS1	3% [46,47]	22% [45,46,47]
Primary KS2	1-2% [46,47]	12%-14%[45,46,47]

Measured noise levels in Early Years settings are significantly higher than those reported in Primary and Secondary classrooms (typically 70-85 dBA), yet children in these settings have reduced phonological awareness, auditory processing and sentence recall skills. This means they require higher SNR compared to their older peers (and adults) to obtain equal speech perception scores, with one study even demonstrating significant difference between 3 year olds (+15 dB SNR), 4 year olds (+10 dB SNR) and 5 year olds (+7.5 dB), in order to achieve the same scores as adults [48].
Even where equal speech perception scores can be achieved, greater cognitive effort is shown to be needed, as evidenced by longer response time (a symptom of listening effort) on speech perception tasks by younger children [49], even where no SEN is present.
Pupils in Early years settings are further disadvantaged due to the highest prevalences of SLCN, EAL (where 55% of EAL pupils are still acquiring proficiency [41]), and mild/temporary hearing loss such as OME, which is more prevalent amongst children attending childcare settings.

Despite the above evidence pointing to children in Early Years being at highest risk of poor acoustic conditions, acoustic standards remain unregulated in nearly all Early Years Settings in England and Wales (except nurseries within school complexes).

4. IMPLICATIONS FOR ACOUSTIC DESIGN

The DfE SEND Code of Practice [50] states that, in order to meet legal obligations under The Equality Act *"schools, early years providers, post-16 institutions MUST make **reasonable adjustments**, including the provision of auxiliary aids and services, to ensure that disabled children and young people are not at a substantial disadvantage compared with their peers. This duty is anticipatory – it requires thought to be given in advance to what disabled children and young people might require and what adjustments might need to be made to prevent that disadvantage".*
The listening disadvantage in relative quiet, critical listening scenarios will increase beyond the reported inherent gap in Table 1 where acoustic conditions are not ideal [4]. Ideal acoustic conditions for listening in quiet, to maintain the inherent listening gap are shown in Table 3.

Table 3 IDEAL ACOUSTICS (SNR/RT) BY NEED

Need	Ideal Acoustic Conditions	
	SNR	RT
$HI_{min-mild}$	+12 dB	0.3-0.4 s
$HI_{mild-mod}$	+20 dB	0.4 s
HI_{S-P}	+20 dB	0.3 s
ASD	+2 to 3.5 dB higher than age matched peers	
APD	+7 dB higher than age matched peers#	
AD/HD	As per age matched peers	
Dyslexia[1]	As per age matched peers	
DLD, SLI	+2 dB higher than age matched peers	
EAL	+2.5 dB higher than age matched peers	
Early Years	+12-15 dB	Not known
Primary	+9-15 dB	0.4-0.5s

Where it is not practicable to provide ideal listening conditions of +20 dB SNR (30 dBA) and 0.3 seconds RT in the mainstream classroom for pupils with the greatest listening need such as hearing impairment (due to constraints a-g listed in Section 1), other factors such as personal listening aids and/or quiet rooms/pods need to be considered.
A **reasonable adjustment** to room acoustic conditions (+15 dB SNR, 0.5 seconds RT) is suitable where these other factors can be realized [4]. This adjusted condition will help

to maintain conditions to protect teachers voice when working in large mainstream classrooms of 25-30 pupils.
A theoretical model was constructed to calculate the SNR at various room positions, based on the models of Nijs & Rychtáriková [68], and Pelegrín-García *et al* [69]. This model indicated that a SNR ≥ 15 dB is achievable as follows:

- 62 m^2 reference classroom, 3.3 m height;
- Listening position towards the back of the room (a reference distance of half the diagonal length);
- Teacher "Raised" vocal effort of 74 dB L_{WA};
- Environmental background noise 40 dBA;
- Student sound power (in quiet) of 35.7 dB L_{WA} from BB93;
- Additional requirements for Clarity, $C_{50} \geq 3$ dB and Unfavourable Ratio, $U_{50} \geq 1.5$ dB;
- Occupied reverberation times between 0.40 and 0.65 seconds are required.

In addition to this, it is also important to limit reverberation time to control buildup of occupied activity noise levels, to help children engage in listening tasks and maintain 0 dB SNR in an active classroom. Based on a teacher ISO 'raised' voice effort and teacher communication to individuals or small groups of pupils at 1.0 m, this would be achieved where the classroom activity noise level is below around 66.5 dBA.
Shield et al [51] surveyed occupied activity noise levels and unoccupied noise levels and room acoustic conditions in a study of secondary schools in England (over 274 lessons in 80 rooms).
New analysis by Shield for the DfE study revealed that occupied lesson noise levels were related to unoccupied indoor ambient noise level ($r^2 = 0.39$; $p< 0.01$) and T_{mf} (r2 = 0.42; $p < 0.01$).
New regression analysis found that, in class sizes of 20 or more, to keep occupied typical L_{Aeq} and L_{A90} levels below those known to affect the performance of pupils (64 dB L_{Aeq} for secondary reading performance [52], 50 dB L_{A90} for SATS performance [53]), indoor ambient noise level should not exceed 35 dBA and T_{mf} should not exceed 0.5 seconds.
By keeping typical activity noise levels below 64 dB, this adjusted condition would also help to avoid triggering of restrictive and repetitive behaviours in pupils with autism which occurred significantly more often in classrooms where the noise level was above 70 dB [54]. Reducing noise levels and reverberation time has also demonstrated effective improvements for children with autism by tripling attention span, improving response time by 60% and improving behavioural temperament [55].

Finally, benefits for early years children would also be realised in the reasonably adjusted classroom condition, since occupied noise levels in daycare facilities were shown to be reduced to 58-68 dBA in classrooms with well controlled reverberation times of up to 0.5 seconds [56, 57]. When reverberation times were improved to reduce noise levels from 76 to 70 dBA in four pre-school classrooms, a post intervention improvement was found in 3-5 year olds' pre-reading skills, language skills, speed of puzzle solving and increased persistence on a task. [58].

5. PERSONAL LISTENING AIDS

Use of personal listening aids are now commonplace in the classroom for children with a significant need such as hearing impairment (including for Cochlear Implant users), and enhance the signal-to-noise ratio irrespective of communication distance. BATOD recommends that *"if ambient noise level [ie signal-to-noise ratio] is controlled then high RT has a minimal effect when a personal listening aid is in skilled use and set up properly"*. Unilateral listening aids have been developed for children with normal hearing to support needs such as ASD, AD/HD, APD, SLCN and these can also be used to support needs such as EAL. Bone conduction listening aids are also available to help children with temporary hearing loss conditions such as OME ('Glue ear'). Systems (including the new Auracast protocol from Bluetooth) connecting to phone based assistive listening apps via headphones are also available which increase accessibility and potentially reduce social stigmas associated with listening aids.
Where it is not possible to rely on or provide personal listening aids to mitigate listening disadvantage in the active classroom, quiet rooms or pods should be considered within the classroom to improve SNR in this mode.
The listening disadvantage in active classrooms can be ameliorated and in some cases eradicated as evidenced in the summary in Table 4.

Table 4 PERSONAL LISTENING AID BENEFIT

Need	Impact of PLA
OME	Not quantified, bone conduction devices possible
$HI_{min-mild}$	Bring your own device aids available
$HI_{mild-mod}$	Disadvantage reduced to 14% in 0 dB SNR [18], close to inherent gap for s-p hearing impairment
ASD	Disadvantage eradicated with PLA [19]
APD	Disadvantage reduced to nearly negligible, from +7 dB SNR needed to +1 dB SNR needed [37]
SLCN	SLCN
AD/HD	Reduced distraction, improved participation and listening in noise. White noise also beneficial for focus [64, 65]
SEMH	SEMH
Dyslexia[1]	Improved reading scores and phonological awareness [63]
DLD, SLI	PLA reduces the dissdvantage in noise [63, 64, 66, 67]

6. COMPARISON WITH OTHER NATIONAL STANDARDS

We have reviewed recent documents comparing different national standards for reverberation times in classrooms, with particular reference to standards for special hearing and communication needs [59 – 62]. A comprehensive comparison is impossible because the numerical values in such documents are only part of any standard; equally important are the conditions to which the standards apply (e.g. in empty, furnished or occupied rooms) and the status and enforcement of the standards (e.g. as guidelines or legal requirements, and whether those requirements are enforced in practice). None the less, a comparison of numerical values gives some useful indication. There is not room in this paper for a complete table of results but our overall findings are described.

Reverberation time standards for mainstream classrooms, with no allowance for pupils with special hearing and communication needs, are generally in the range 0.4 to 0.6 seconds although a few countries allow values of up to 0.8 seconds. The current UK standard of 0.8 seconds T_{mf} in secondary schools is among the least stringent of those reviewed and would not be acceptable in many countries.

Reverberation time standards for classrooms designed to accommodate pupils with special hearing and communication needs are generally in the range 0.3 to 0.5 seconds although a few countries allow values of up to 0.6 seconds. The current UK standard of 0.4 seconds across an extended frequency range would be considered acceptable in most countries. Comparisons are, however, very difficult because of the widely different interpretations of when a classroom should be designed to the SHCN standard.

In many countries the RT criteria are linked to room volume by a simple formula, or different values are set for different classifications and sizes of classrooms. None of the literature or anecdotal evidence suggests that a volume-dependent RT criterion causes any problems with understanding or implementation of the criteria.

There has been a general trend in recent years towards setting more stringent standards, i.e. shorter RTs. In some cases this is through a revision of the numerical standards and in others through re-classification of room types acknowledging the need for inclusion of pupils with special hearing and communication needs.

In general, our reasonable adjustment proposal for T_{mf} not to exceed 0.5 seconds in normally-sized mainstream classrooms would be consistent with that in most other countries.

7. FUTURE WORK: USER-CENTRIC ACOUSTIC DESIGN FRAMEWORK

This work has emphasized the importance of the concept of the activity for which the acoustic design is required. For example, Prodi and Visentin [70] examine the effect of reverberation time on typical tasks of daily classroom activities in two different listening conditions (quiet and classroom noise). Various researchers can come to different conclusions about optimal room acoustic response for different classroom activities. Overall, it is necessary to categorise the different activities, and prioritise appropriately. There are design conflicts, for example, between the room providing sufficient support for the teacher's voice on the one hand, and the room avoiding the build up of reverberant sound during group activities, on the other.

An output from this work is a proposal for a framework to enable a systematic approach to determination of optimal acoustic conditions. By extension, identification of minimum acceptable acoustic performance requirements could also be identified. The framework starts from the activity, for which the acoustic challenges are identified. Appropriate acoustic performance criteria can be derived for these activities from the literature, and suitable performance values identified for mainstream and inclusive environments.

8. SUMMARY

The differing listening needs for students with different types of special hearing and communication needs (SHCN) have been identified in the literature, and the listening disadvantage is quantified. The prevalence of each listening need in mainstream schools in England and Wales, and the typical listening disadvantage associated with each need in both quiet and active classrooms is reviewed. Suitable reasonably adjusted acoustic performance standards in mainstream schools are established for each need, together with provision of listening aids and other design measures, in order to support access to listening. Future work could present the various drivers of room acoustic performance within a user-centric framework, to facilitate understanding and prioritise the most important activities in different types of spaces.

9. ACKNOWLEDGMENTS

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