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Architectural acoustics and parliamentary debate: Exploring the acoustics of the UK House of Commons Chamber.

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ABSTRACT

The United Kingdom's House of Commons chamber is a theatre for confrontational political performance, speech-making and Parliamentary debate. The space has been subject to considerable architectural change due to historic events such as the Reformation, the English Civil War, the fire in 1834, and destruction in the Second World War. Considering its importance in shaping the history of the UK, together with the political speeches, performances and decisions that have taken place within it, we explore and compare the acoustic characteristics of the House of Commons Chamber in different contexts. Acoustic results are obtained from measurements carried out in the modern House of Commons chamber, and the University of Oxford's Divinity School and Convocation House as alternative spaces used for Parliamentary debate in the 17th century. An overview of the acoustic parameters and a comparison between them is presented, with a specific focus on speech intelligibility and the perception of speech in the context of Parliamentary debate. Auralisation examples are provided as a listening experience of these spaces and the data will be used to inform further acoustic modelling work of the historic House of Commons chamber site within the Palace of Westminster.

Keywords: Speech intelligibility, House of Commons, Measurements

1. INTRODUCTION

The House of Commons of the United Kingdom has changed locations and buildings several times due to political changes and damage to the spaces over a number of centuries. St Stephen's chapel in the Palace of Westminster was dissolved during the Reformation of Edward VI, redesigned in 1692 with wooden panels covering the main structure, followed up by several stages of layout changes of the seats and gallery until 1834 when a fire in the Palace destroyed the building which was then demolished in 1837 [1]. The new building was then designed with the same architectural style which has been copied until the very modern House of Commons. Over the course of some of these changes, Parliament had met in several other locations including the Convocation House and the Divinity School at the University of Oxford.

The uniqueness of Parliamentary spaces is the fact that they require good speech intelligibility across all the members' positions. Each member of the parliament is not only the receiver of the speech taking place in the space but could potentially be the speaker. This is particularly challenging in a rectangularly shaped space, where the benches are arranged in parallel rows across the length of the room facing each other for debating.

This layout is influenced by the choir stall arrangements of the medieval St Stephen's Chapel where Parliament sat between the 16th-19th century. There have been several discussions over the years regarding the effectiveness of this layout and its impact on the meetings that took place.

There are studies discussing speech intelligibility parameters for spaces such as schools, churches, and theatres. As part of the Past Has Ears project [2], our aim is to reconstruct the acoustics of the historic St Stephen's Chapel as it was used before the fire in 1834 and explore the impact of its acoustics on Parliamentary debates. In this paper, we are interested in the investigation of the acoustics, and specifically the speech intelligibility of three existing spaces used for Parliamentary debates. The acoustic analysis and auralization results are based on impulse responses obtained from in situ measurements by a different scientific team (see acknowledgements).

2. PARLIAMENTARY SPACES

2.1 House of Commons chamber, Westminster

The current House of Commons in Westminster Palace (Figure 1) was designed by Sir Giles Gilbert Scott and completed in 1950, after the previous chamber was entirely destroyed by bombing during World War II in May 1941. It was deliberately rebuilt following the architectural style and political culture

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of the previous chambers. Members of the Parliament may speak from where they are seated, except for the floor area between the red lines, which traditionally is said to be two sword-lengths apart.

From the available acoustic measurements, two source locations have been chosen; one being at the Speaker of the House of Commons' Chair, and one to their left, where the Opposition Leader stands, as due to the symmetry of the space, similar results would have been obtained from a source at the dispatch box, where the Prime Minister usually stands. Measurements were taken with the following combinations of source/receiver positions; 1:S1-R1, 2:S1-R2, 3:S1-R5, 4:S1-R3, 5:S1-R4, 6:S2-R4, 7:S2-R5 and 8:S2-R6 (Figure 2).

Figure 1 – Chamber of House of Commons, in Westminster in its current condition [3]

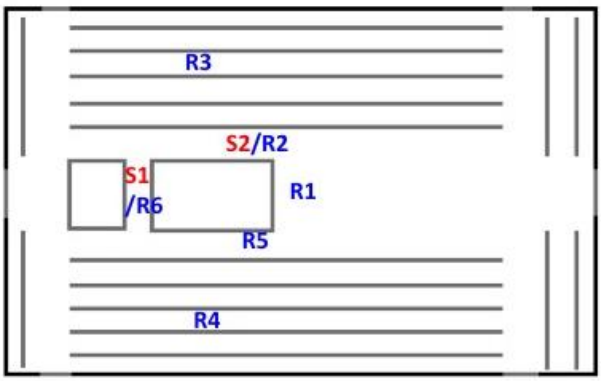

Figure 2 – Measured positions in House of Commons, Westminster, dimensions: 21m x 16m x 14.7m, Volume: without furnishing 4839m^3

2.2 Convocation House, University of Oxford

Convocation House is part of the University of Oxford's Bodleian Library (Figure 3), built in 1634. During the English Civil War and in 1665 and 1681 it was used for meetings of the House of Commons.

The measured positions for this study are shown in Figure 4. Three different sound source locations were considered; one at the Speaker's position (S1), S2/R2 and S3/R5 representing members of the Parliament who could have also been listeners/receivers in different source combinations. Additionally, four more receiver positions were spread symmetrically in the space (R1 - R6) resulting in the following combinations of source/receiver positions; 1:S1-R1, 2:S1-R2, 3:S1-R3, 4:S1-R4, 5:S1-R5, 6:S2-R1, 7:S2-R3, 8:S2-R4, 9:S2-R5, 10:S2-R6, 11:S3-R1, 12:S3-R2, 13:S3-R3, 14:S3-R4 and 15:S3-R6 (Figure 4).

Figure 3 – Convocation House, University of Oxford, Photo by DAVID ILIFF. License: CC BY-SA 3.0 [4]

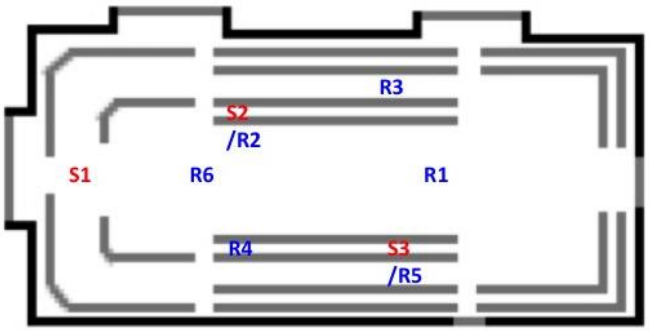

Figure 4 – Measured positions in the Convocation House, Oxford, dimensions: 18.55m x 8.4m x 7.63m, Volume: without furnishing 1177.9m^3

2.3 Divinity School, University of Oxford

Divinity School (Figure 5) is also part of the Bodleian Library at the University of Oxford and adjacent to Convocation House. In 1625 and during the English Civil War, the House of Commons had sat in Divinity School. One measurement was arranged here, with the source and receiver set in central positions (Figure 6).

Figure 5 – Divinity School, University of Oxford, Photo by DAVID ILIFF. License: CC BY-SA 3.0 [5]

3. RESULTS

The acoustic measurements were carried out with a Genelec 8030 as a sound source and a Soundfield

ST450 microphone as the receiver and using an exponential sine sweep of length 15s. For the analysis, MATLAB was used to post-process the recorded files, while Aurora plug-in was used for the traditional ISO3382 acoustic parameters such as T30, EDT and C50. The impulse responses were also imported into ODEON for the calculations of speech intelligibility parameters. The values of the background noise observed from the Aurora plug-in also were imported into ODEON for each individual octave band frequency for each of the impulse responses.

Figure 6 – Measured position in Divinity School, University of Oxford, dimensions: 27.6m x 10.3m x 7m, Volume: without furnishing 1989.9m^3

Three parameters are presented and analysed here. We start with reverberation time (T30) for an overall impression of the acoustics of the studied spaces. Clarity (C50) is analysed as it is associated with the perception of speech. It has also been considered that for this study Speech Transmission Index (STI) provides sufficient information regarding the speech intelligibility of the spaces across the different measured positions. For each space, we use the following abbreviations; HoC for House of Commons, CH for Convocation House and DS for Divinity School.

3.1 T30

Figure 7 shows the results of T30 calculations from the three spaces. For the HoC and CH, the curves show the octave band average values across all measured positions, with error bars to indicate the variance of the results for each frequency band, while the results for DS are based on the single available measurement. As expected, the variations between the multiple positions are minimum, while the curves of the HoC and CH follow a typical pattern for such spaces. Reverberation time is much shorter in the HoC, as this is a modern space compared to the CH or DS, and was built to fit the purpose of its use. Note that T30 is quite high for DS and for 500-4kHz octave bands for CH.

3.2 C50

Figure 8 shows the octave band averaged results for C50 for all 3 spaces with error bars across. It was observed that two locations, Position 7:R2-R5 from HoC and Position 8:S2-R4 from CH, were significantly different from the rest of the locations for each space.

Their values have been excluded from the average values, and have been represented here with no fill on markers in order to demonstrate their differences from the rest. Further detailed analysis of these locations showed that Position 7:R2-R5 from the HoC is in the near field of the sound source, and any acoustic measurements are not representative of the acoustic behaviour of the space. It is interesting to note that their distance is 3.3m, which is within the 2 swords' length (3.9m) that the tradition required. For the exceptional position in CH, the different acoustic behaviour could be a result of standing waves due to the parallel walls in that specific location, or comb filter effects from a wooden stand/table placed nearby as some possible frequency interference was observed in the frequency analysis. Overall, it was observed that the results of the modern HoC are above 0dB across all the frequency bands, indicating very good clarity for speech purposes. On the other hand, CH and DS have poor clarity, with C50 values below 0dB.

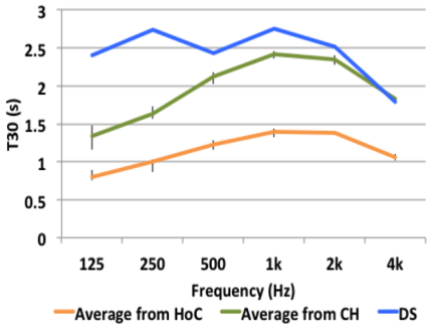

Figure 7 – T30 results from the three spaces

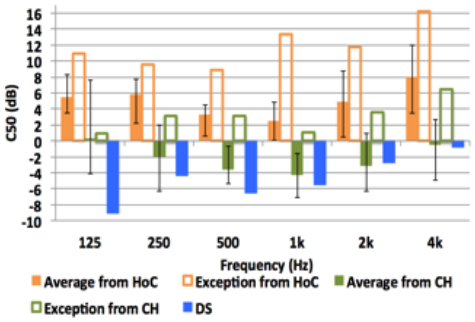

Figure 8 – C50 results from the three spaces. The solid lines represent the average values of the positions with standard deviation across the frequency bands. Particular locations for HoC and CH have been excluded from the average results, although being presented for reference

3.3 STI

The Speech Intelligibility Index is evaluated based on the STI label categories from ISO 9921. The range of measured outcomes is shown in Figure 9, as well as the results of the measured positions for each of the three spaces. Two points, as discussed above, for Position 7 of the HoC and Position 8 of the CH have been left with no fill on markers, indicating their differences from the rest of the results. The STI results from the HoC are *good* to *excellent*, from CH are *fair*

while the single position in DS has *poor* speech intelligibility.

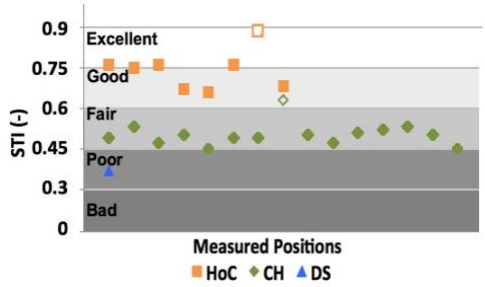

Figure 9 – STI results from the three spaces across the different measured positions

4. AURALIZATION RESULTS

An excerpt of an anechoic recording from the speech made by Henry Beaufoy to the HoC in 1792 on the slave trade was used for this purpose. The performer for this recording, one of the authors of this paper, is an English native speaker. The W channels of the ambisonic recordings have been convolved with the anechoic recordings and the MONO results are available at the Open AIR Library [6].

The objective results analysed above can be confirmed from the listening examples. The intelligibility of the speech in the HoC is significantly better than the auralization examples from CH and DS. In the last two spaces, the reverberance of the space has a negative impact on speech perception.

5. CONCLUSIONS

We have studied three spaces that have been used or are still used for meetings of the UK Parliament. The layout of the seats is of particular interest and is challenging due to the fact that all the receivers in the Parliamentary spaces are potential sound sources too.

Overall, the modern House of Commons has low values of T30 and high values of C50, representing an excellent space for its purpose. STI values have also confirmed this result, indicating good to excellent speech intelligibility. Note that there is a complex sound reinforcement system built into the benches of the House of Commons chamber that is used to enhance speech further for all listeners although this was turned off during the measurement process.

Convocation House and Divinity School have longer reverberation time, affecting C50 and STI values correspondingly. The spaces are rated between poor (for Divinity School) and fair (for the Convocation House) for their speech intelligibility. While their main use was for lectures and meetings of the University members, the acoustics are not appropriate for this purpose. The above results indicate that Parliamentary meetings in both these spaces would have been a challenge to comprehend and participate effectively in debates across the measured positions. Further source/receiver combinations, however, for these spaces would also support our investigation in this paper.

The current results will be used to inform and calibrate the reconstruction of the historic chamber model of the House of Commons as it was before the fire in 1834, as the main focus of the PHE project.

ACKNOWLEDGEMENTS

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