Applied Acoustics 88 (2015) 38–43

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Technical Note

Objective evaluation of a simulation of the acoustics of a medieval urban space used for dramatic performances

Mariana Lopez

Cultures of the Digital Economy Research Institute, Anglia Ruskin University, Cambridge CB1 1PT, United Kingdom

ARTICLE INFO

Article history:
Received 3 June 2014
Received in revised form 1 August 2014
Accepted 10 August 2014
Available online 29 August 2014

Keywords:
Acoustical heritage
Acoustic parameters
Medieval drama
Outdoor acoustics
Urban space

ABSTRACT

This paper explores the use of a computer model to study the acoustics of Stonegate, a street in central York (UK) used as a performance site of the *York Mystery Plays* in the Middle Ages. A computer model was designed to resemble modern Stonegate due to the state of conservation of many of its fourteenth- and fifteenth- century buildings as well as its dimensions. The virtual model was evaluated objectively by comparing the results for different acoustical parameters obtained through acoustic measurements on site with those derived from the virtual model. The objective comparison showed a high level of accuracy for all parameters studied with the exception of EDT and $IACC_L$. Future work will involve using this initial computer model to study the acoustics of the space in the sixteenth century.

1. Introduction

Research on the relationship between acoustics and drama performances throughout history has been extensive [1]. However, research on pre-seventeenth century theatre acoustics has focussed either on Greek and Roman [2–12] or Elizabethan theatre [13,14] leaving aside the study of medieval drama acoustics. The study of medieval acoustics instead has been centred on churches as worship spaces and as sites for the performance of liturgical music [1,15–18]. The only study on medieval drama and acoustics known to the author focusses on the liturgical drama *El Misteri d'Elx* dating from *c.*1450, which was performed in the Basilica of Santa Maria in Elche, Spain [19]. Although it studies a piece of medieval drama, it focusses once more on the effects of the acoustics of a church on the performance of sung items.

Acoustical studies to date have not considered the performance spaces used for medieval religious vernacular drama, that is, a group of plays in the vernacular and with a religious subject matter that, in the case of England, were first performed in the fourteenth century [20]. This form of medieval drama not only included the spoken word, but also incorporated music in the form of plainchant or polyphonic items [20]. Although plays were mainly performed outdoors using temporarily assembled stages [21], acoustics would have still been a key consideration. The spaces available for the performance could have been modified to improve acoustic conditions, in particular to ensure speech intelligibility and audience engagement. Furthermore, the inclusion of plainchant items in most medieval plays also poses some relevant questions. Performers and audiences would have normally sung or listened to these pieces within the acoustic settings of churches but within the performance of the plays the pieces would have been transformed by the contrasting outdoor acoustics. Such a change would have affected both singers and audiences. Singers might have had to modify their performance to suit the acoustics of the space; whereas audiences would have also noticed the change and may have reacted differently as a consequence.

The *York Mystery Plays* are an example of medieval religious vernacular drama [20]. They are a series of forty-eight plays that narrate events of relevance to the Christian faith and were performed regularly in the streets of York from the fourteenth to the sixteenth century. The performances were staged on wagons that were specifically constructed for the occasion and were manhandled through the streets of York. The wagons followed a predetermined route through the city and stopped at stations (street spaces) where an audience gathered to see the performance.

In the Middle Ages speech and music were considered essential to Christianity as they were means through which to communicate with God and the divine message [22–24]. The *York Mystery Plays* in turn, also aimed to reverence Christ and transmit religious doctrine [25,26]. As a result, the lines delivered and the music performed would have needed to be as intelligible and engaging as possible so that the Christian message could be transmitted to the audience. Therefore, it is difficult to conceive of staging and

E-mail address: mariana.lopez@anglia.ac.uk

http://dx.doi.org/10.1016/j.apacoust.2014.08.003
0003-682X/© 2014 Elsevier Ltd. All rights reserved.

performance decisions that did not consider acoustics as crucial for the performance of the plays.

One of the better-preserved sites of the performances is found at Stonegate, a street in central York. The preservation of buildings from the fourteenth and fifteenth centuries together with the fact that the street dimensions have been mostly maintained from the period of interest to the present [27], make Stonegate a suitable site for an acoustical study. A previous study explored the acoustics of this site through impulse response measurement techniques applying the Exponential Sine Sweep (ESS) method and using a 90-second sine sweep [28]. One source and three receivers were positioned at one of the stations in Stonegate used for the 1569 performance [29,30] (see Fig. 1). To ensure the validity of the results, the impulse response measurements were conducted only after a pilot study [31] and an experiment in a controlled environment [32] had been completed in order to determine the suitable method for measurements in Stonegate. Furthermore, when possible, measurements for each source–receiver combination were conducted more than once to check repeatability as well as the effects of time variance [28].

Results demonstrated that Stonegate as it stands today possesses a short reverberation time and high clarity, which are features that are beneficial for speech intelligibility and as a result suitable for the spoken extracts of the plays. However, those same characteristics make it a less satisfactory space for the performance of plainchant items, which are better suited to spaces with a long reverberation time and low clarity [1,15]. The study of the $IACC_E$ (Interaural Cross-correlation Coefficient-Early), on the other hand, demonstrated that Stonegate has high levels of Apparent Source Width (ASW), which indicates the perceptual broadening of the sound source and is an acoustic feature coveted for music performance spaces.

The present paper explores how the acoustic measurements conducted in Stonegate were used as the basis for the design of a computer model of the space as it stands today in CATT-A and it describes how objective methods were used to evaluate the computer simulation. This paper examines the first phase of a larger project that has the aim of using the computer model of modern Stonegate to study its acoustics in the sixteenth century as well as the impact of staging techniques on the spoken and sung elements of the plays.

2. The acoustics of modern Stonegate: The computer simulation

The acoustic measurements conducted in Stonegate [28] provided an insight into the characteristics of the space as it stands today, which is of great value due to the state of conservation of some of its medieval features. However, to arrive at a deeper understanding of the acoustics of the space at the time of the performance of the *York Mystery Plays* it is necessary to use computer simulations. This section will explore how a virtual model of Stonegate as it stands today was designed and its results evaluated as a first instance towards the understanding of the acoustics of the space in the sixteenth century.

2.1. Calibrating the computer simulation

A computer model of modern Stonegate was created using CATT-A [34]. Geometrical data for the construction of the virtual model was gathered using modern photogrammetry techniques and with the aid of the application Autodesk 123D Catch [35]. The virtual model consists of 454 planes and includes both sides of the street as well as a portion of Little Stonegate (see Fig. 2). One source and three receivers were added to the virtual model to replicate the positions, head direction and directivity of those used for the on-site measurements (see Fig. 3).

The selection of absorption coefficients was carried out through a process of calibration, which involved a comparison between the results of the virtual model and the on-site measurements for each acoustical parameter studied considered individually. The acoustical parameters considered were related to reverberation time (T_{20}, T_{30} and Early Decay Time-EDT), clarity (C_{50}, C_{80}) and Spatial Impression ($IACC_E$, LF-Early Lateral Energy Fraction, $IACC_L$-late). Results were considered per source–receiver combination and frequency band, that is, no averaging was applied to the numerical values. The aim of the calibration process was to arrive at objective values for the virtual model comparable to those recorded on site.

Scattering coefficients for the model of Stonegate were determined by applying the same process of calibration. The determination of scattering coefficients could not be done through the use of surface property libraries, as values for most surface materials are not easily available and in CATT-A they are limited to audience-related surfaces and diffusers. Measuring the scattering coefficients for this project was not possible as it would have required the use of a reverberation chamber as well as samples of the materials in question [36], which were not available. CATT-A guidelines suggest using both low and high values alternatively to check for the sensitivity of the results to the changes [37]. The default surface scattering coefficient in CATT-A is 10% and the software developer recommends this value for large flat smooth surfaces [37]. This recommendation was followed and rougher surfaces were given higher scattering coefficients, with the highest value being

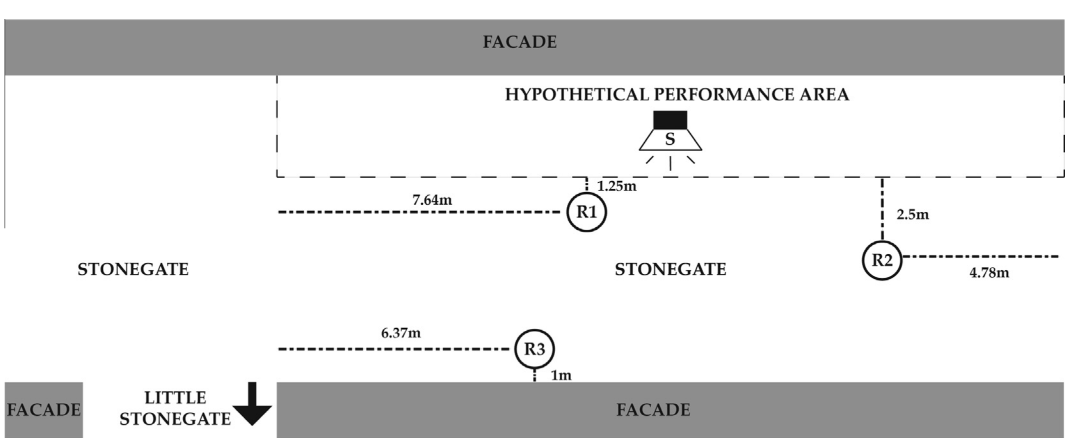

Fig. 1. Bird's eye view of a section of Stonegate, a street in central York (UK). The diagram indicates the area used for the impulse response measurements, including the sound source (S) and the receiver positions (R). The receiver positions used follow the indications in [33].