CHAPTER 5
Audiovisual Interaction in Spatial Impression[1]

As the overall spatial impression is likely to be formed from both auditory and visual cues, this chapter explores the effects of auditory and visual impression on each other. In a combined audiovisual experiment, the auditory and visual spatial impressions are judged by subjects using greyscale projected photographs, and anechoic orchestral recording convolved with binaural impulse responses measured from the same positions in Hall C. The experiments presented the photographs and recordings simultaneously.

Results show that, by comparison between test modes, combining audiovisual stimuli in subjective experiments is of primary importance in discovering the degree to which auditory and visual spatial impression affect one another. The audiovisual interactions appear to be strong in some cases, and weak in others. Nevertheless, the results seemed to suggest that audiovisual interaction would be useful to be further explored for application in new designs of auditoria, such that reconfiguration of a performance space is possible; thereby engendering certain specific audiovisual spatial impression.

[1] (Nguyen, A, & Cabrera, D., 2004b), *invited paper, 148th Meeting of the Acoustical Society of America, San Diego, California, USA.*

5.1. INTRODUCTION

Hall C (Verbrugghen Hall), the smallest of the three halls in the series, is the only hall studied in this last part of the research project on spatial impression. In the beginning, the thesis suggests there should be some interaction between the auditory and visual spatial impression in a musical experience in a concert hall. Based on this assumption, the study is investigating the degree of correspondence (or contrast), and interaction between auditory and visual spatial impression within one auditorium.

Auditory visual interaction is not a marginal research interest in the acoustics community; however, it is certainly an under studied area. In auditorium acoustics, however, there has been a growing interest in recent years to explore further the value of auditory and visual interaction in the symphonic concert experience. Perhaps there are factors (controllable or not) of the visual aspect in a concert hall that would either enhance or distract from the auditory experience.

A recent study by Larrson et al (2004) found that there are audiovisual interaction effects when perceiving rooms. However, there is no known systematic organization or characterization of these effects. They suggest that simulation quality of subjective experiments is most likely to influence the ratings of acoustics, and possible visual, attributes. Several experiments were conducted. One experiment is particularly relevant to the present study as it explores audiovisual interaction in a concert hall, at least in a synthetic context. It involves a virtual reality simulation of a small concert hall (369 seats) with a 19-channel Reverberation Enhancement System (RES) using CATT acoustics auralisations of the room with varying levels of reverberation enhancement. The audio stimuli were generated from sound sources of a clarinet, string quartet and a male voice.

Groups of 75 subjects participated in three different experiment conditions, sound only, sound with picture, sound with picture and RES loudspeakers visible. They were asked to judge "reverberation time," "auditory room size," "auditory distance to sound source," and "auditory source width," by listening alone, or listening and viewing (an image) simultaneously.

The results show "reverberation time," "auditory source width," and "distance to sound source" were rated longer (or larger) in the "sound only condition" as compared to the "sound with picture condition." "Auditory room size" was rated smaller in the "sound only" condition as compared to the "sound with picture" condition. However, Larrson et al suggest that these "effects depend on the type of sound source, setting of RES level, and listener position."

Larrson et al's study was published at the same time the present study was in progress. This particular study is important in relation to the objective of this thesis, as other studies of audiovisual interaction do not involve concert auditoria. It is important to this present study because Larsson et al. found that the auditory perception of the stimulus changes as a visual stimulus is introduced simultaneously.

Audiovisual interactions occur in numerous audio and physical environments such as audiovisual interactions in loudness evaluation (Fastl, 2004) and perceived loudness relative to room's light level (Larson et al., 2004). Although Fastl dealt with noise and environmental acoustics rather than auditorium acoustics, these findings have potential usefulness in architectural and auditorium acoustics. Both of these studies present a continuing interest in audiovisual interaction in rooms, and especially in auditorium acoustics where design flexibility is possible. As Larrson et al, and Marshall (2004) suggest, further understanding of audiovisual interactions, particularly in auditorium design, would lead to better design, and increased understanding and make the collaborative process between acousticians and architects more productive. Thus, the better the collaborative process, the greater the possibilities of engendering a richer and more diverse spatial experience for the audiences of concert auditoria.

5.2. AIM

The previous study, in Chapter 4, was conducted using auditory and visual experiments separately to compare the auditory and visual spatial impression within Hall C. In this study (a combined audiovisual experiment), the results are compared to the previous separated auditory and visual experiment. As a case study, it investigates the degree of interaction between auditory and visual spatial impression in Hall C. If the results show a difference (or discrepancy) between the ratings of the separate and combined experiment, it should suggest that there is an interaction between the auditory and visual senses. Thus, these findings would be useful in application for new designs of auditoria, such that the reconfiguration of a performance space is possible; thereby engendering certain specific audiovisual spatial impression.

5.3. METHOD

5.3.1. Audio and visual stimulus generation

Binaural impulse responses were measured in Hall C using a Brüel & Kjær Head and Torso Simulator (HATS), and a loudspeaker in the centre of the stage. The HATS ears were at a height of 1.2 m above the floor, and the loudspeaker at a height of 1.4 m, in the centre of the stage. In Hall C, a Meyersound VPA loudspeaker was used as the measurement source. Impulse responses were obtained from logarithmic sine sweeps (20 Hz – 20 kHz, 5.4 s). Refer to Table 4.1 for the list of receiver positions. These responses were extracted and analysed using Aurora software (Farina, 2000), yielding 2.5 to 3.5 seconds of impulse response data. Measurements were calibrated, so that the sensitivity of the two ear channels could be matched, and the variation in sound pressure level through each auditorium could be maintained.

Seat Number	Distance from Source	Angle from Midline	Gallery or Stalls
D12	10 m	0°	Stalls
D17	10 m	15°	Stalls
D7	10 m	15°	Stalls
I12	15 m	0°	Stalls
I19	15 m	15°	Stalls
I5	15 m	15°	Stalls
M21	20 m	15°	Stalls
M3	20 m	15°	Stalls
O10	20 m	0°	Stalls
GA10	20 m	0°	Gallery
GC10	22 m	0°	Gallery
GE10	25 m	0°	Gallery

Table 5.1: Measurement positions (in Hall C) represented by the auditory and visual stimuli.

An anechoic recording of the opening 10 seconds of the Overture to Ruslan and Ludmilla (Glinka) (Dennon, 1993b) was convolved with the measured impulse responses to create the subjective experiment auditory stimuli. As this experiment used Sennheiser HD600 headphones, the transfer function between these headphones and the HATS ear simulators was compensated for through 1/3-octave band digital equalization.

Several reasons for redoing the impulse response measurements in Hall C were to complete the measurements of the gallery seats, and to use a similar loudspeaker to the measurements in Hall A (refer to Chapter 4), so that a impulse response comparison between

Hall A & C may be done in the near future. Further discussion regarding the new measurements and their impact on this current study can be found in the Discussion section.

The same photographs were used as described previously in chapters 3 & 4. Table 5.1 lists the visual stimuli used in this experiment. The grey scale images were presented, using MS PowerPoint, on a laptop computer with a 14-inch monitor.

5.3.2. Auditory experiment

Subjects listened to the stimuli in an anechoic room using headphones. Although anechoic conditions were not required, the low-noise floor of this room (of 18 dBA) was presumed to be important in allowing subjects to hear the sometimes-subtle differences between the sound stimuli. A black curtain covered the absorptive wall in front of the subjects to reduce visual distraction.

Eight subjects participated in this experiment. Six of them, who were members of a choir, had never participated in any listening test and were mostly unfamiliar with the concepts of spatial impression such as ASW, LEV and intimacy. The other two subjects are students in the audio design program and are mostly familiar with the concepts of spatial impression. Regardless of the level of familiarity, the concepts of auditory spatial impression were defined and explained to all subjects and illustrated graphically to ensure that they responded meaningfully to the scales. Subjects listened to all stimuli before beginning their assessment of the auditorium. Three audio compact discs were prepared containing all stimuli in each, in distinct randomly-determined orders. Subjects listened to one of these discs for training, and another for the experiment. Thus, stimulus order was systematically varied between subjects, such that no two subjects had the same overall stimulus order.

ASW, LEV and Intimacy were rated on a discrete integer scale ranging between 0 (defined as 'none') and 10 (defined as 'maximal'). Source distance was estimated in meters. Table 4.2 (in Chapter 4) summarizes the characteristics of the auditory stimuli, either in terms of the impulse response properties or binaural measurements of the actual stimuli. As the impulse responses were measured using the same method as described in Chapter 4 and the same auditorium (Hall C) as used in the previous experiment, the impulse response properties should not change (refer to Appendix 2 for the experiment result data). The previous auditory experiment used only the impulse responses measured on the floor area but not the gallery;

this made it necessary to redo the measurements to include measurement positions in the gallery of Hall C.

No visual-only experiment was conducted for this study; the data used in the analysis is taken from the previous visual experiment discussed in Chapter 4.

5.3.3. Audiovisual combined experiment

Subjects listened to the audio stimuli and viewed the images in a quiet room using headphones. Seven subjects participated in the combined audiovisual experiment. The 12 audiovisual stimuli were presented twice, each subject responded to the auditory and visual questionnaire separately. Two audiovisual tests were prepared containing all stimuli in each, in distinct randomly-determined orders. Three of the 7 subjects completed the visual questionnaire first, and the other four completed the audio questionnaire first.

As mentioned earlier, the audio and visual stimuli were presented simultaneously, but using two different pieces of equipment. The subjects were allowed to control the length of time spent for each audiovisual stimulus. However, the sound level and image brightness were not adjustable.

For the auditory spatial impression questionnaire, ASW, LEV and intimacy were rated on a discrete integer scale ranging between 0 (defined as 'none') and 10 (defined as 'maximal'). Source distance was estimated in meters. For the visual spatial impression questionnaire, spaciousness, envelopment, stage dominance, and intimacy were also rated on the same discrete integer scales as in the auditory questionnaire. The subjects also estimated viewer to target distance in meters.

This experiment was a replacement for an audiovisual combined experiment, since it was discovered that, after that particular experiment was completed, the playback audio stimuli were not binaural but diotic (meaning mixed to mono in the playback system). Appendix 6 shows a comparison between the result of the binaural and diotic experiments.

5.4. RESULTS

As the auditory and visual spatial impression subjective tests were conducted in separate sessions, they are separated in the analysis (although they are charted together in the figures). Analysis of variance (ANOVA, factorial) was used to test the significance of differences in subjective ratings for the single independent variables of “test mode” and “seat.”

For the combined audiovisual experiment, the results show auditory or visual subjective judgments of the audio or visual stimulus when a visual or audio stimulus is present. The subject was not judging the audiovisual sample, but rather the audio and visual part of the sample. It is the aim, as stated earlier, is to find out what the effect is (if any at all) on the subject’s judgment of an audio or visual stimulus when there is a visual or audio stimulus present.

In preparation for the comparative analyses, the analysis of auditory experiment results was completed[2] and visual experiment results were taken from the previous study. ANOVA showed “seat” has a significant effect on the auditory scale ASW, LEV and Intimacy, Estimated Distance, and the visual scale of Spaciousness, Stage Dominance, Intimacy, and Estimated Distance. Non-significant results were obtained for the visual scale of Envelopment (P=0.72). Refer to Appendix 4 for the complete statistical analyses.

Two comparative analyses were completed. First, between audiovisual and audio only experiment, ANOVA showed “test mode” has a significant effect on auditory distance estimation (P<0.0001), and has no significant effect on the auditory scale of ASW (P=0.2), LEV (P=0.28), and Intimacy (P=0.18). The second comparative analysis, between audiovisual and visual only experiment, ANOVA showed “test mode” has a significant effect on the visual scale of Spaciousness, Stage Dominance, Intimacy, and Envelopment and no significant effect on visual distance estimation (P=0.05).

In the separate analysis of the audiovisual experiment results, ANOVA showed “seat” has a significant effect on the auditory scale of ASW, LEV, Intimacy, and Estimated Distance, and the visual scale of Intimacy, and Envelopment; and has no significant effect on the visual scale of Stage Dominance (P=0.69), and Spaciousness (P=0.80).

[2] These results are slightly different to the previous auditory experiment (ANOVA showed a significant result for ASW as to non-significant previously). Appendix 5 compares the two ASW results and offers a discussion as to the possible causes for this discrepancy.

5.4.1. Apparent Source Width and Listener Envelopment:

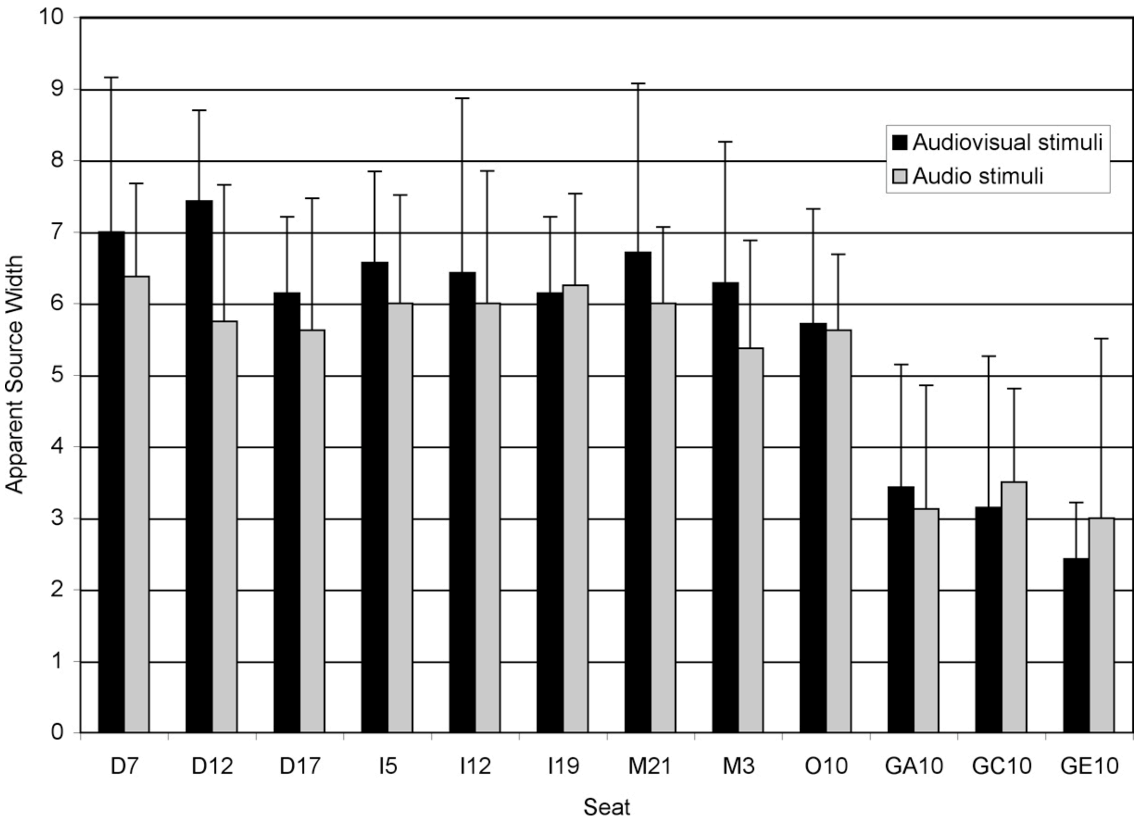

Figure 5.1: ASW ratings (with standard deviations) comparison (with standard deviations) comparison between audiovisual and audio stimuli experiments, refer to table 5.1 for distance & angle relative to source point.

The graph above shows ASW rating compared between seat locations and between the audiovisual combined and audio only experiment. Seat D12 shows the largest different in ratings between audiovisual combined stimuli and audio only stimuli. ASW ratings of both audiovisual and audio stimuli for seat I19 (near the centre of the hall) and O10 (at 20m on the centre line) appear to closely match more than any other seat locations. Seats GC10 and GE10 (at 22 and 25 m respectively) show ASW ratings of audio stimuli about half a point higher than those of audiovisual stimuli. However, ANOVA shows "test mode" to have an insignificant effect on ASW (P=0.2)

ANOVA shows "seat" to have a significant effect on ASW (P<0.0001) when analysing the audiovisual results. ASW rating decreases only slightly as source receiver distance increases (Appendix 3.1.2, Figure A3.1). However, the gallery seats ratings (GA10 to GC10) appear markedly lower than the rest of the seats in the hall.

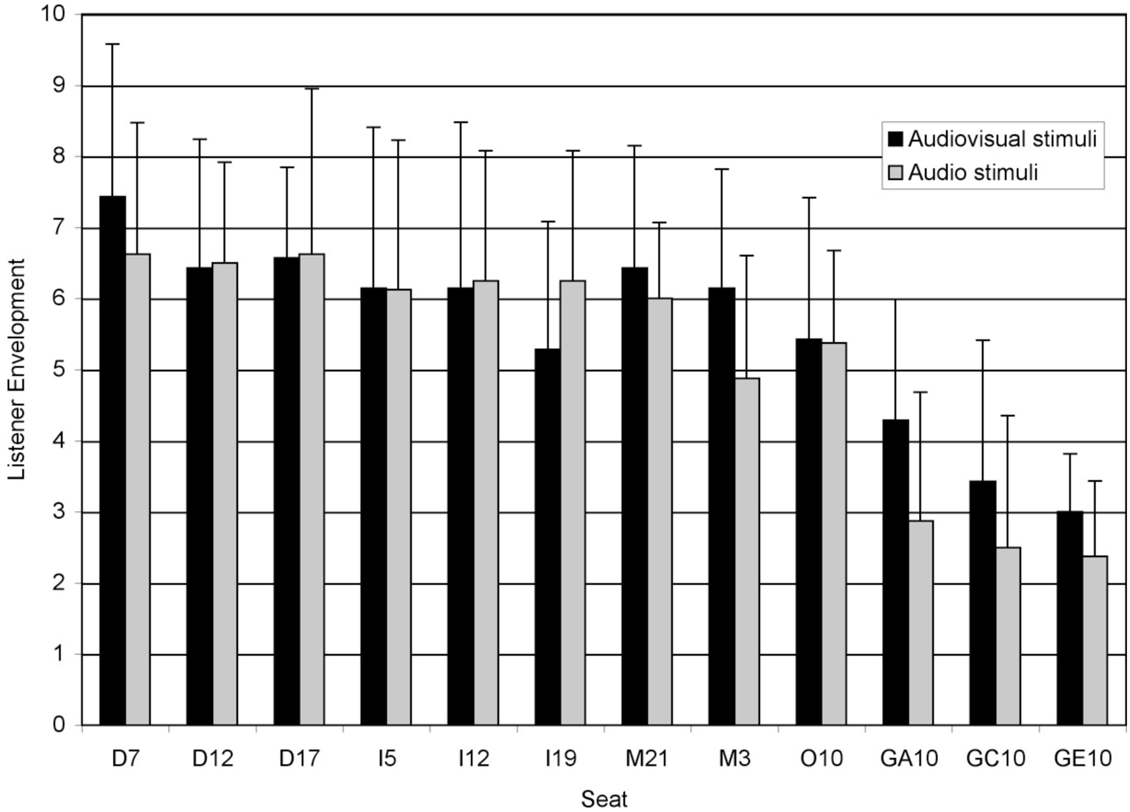

Figure 5.2: *LEV ratings*.

LEV ratings of audiovisual stimuli, at most seat locations on the floor area (D7 to O10), appear to be closely matched to those of audio stimuli. The rating of audiovisual stimuli is lower than that of audio stimuli for seat I19 (near the centre of the hall) and I5 (at 15m left of centre line). By visual indication on the graph, the ratings of seats from D7 to M21 appear to be quite similar. On the gallery, seats GA10 (at 20m on centre line) show LEV ratings audiovisual stimuli the highest of any other seat location. Again, ANOVA shows “test mode” to have an insignificant effect on ASW (P=0.28).

When analysing the audiovisual result separately, ANOVA also shows seat location to have a significant effect on LEV (P=0.0005). LEV ratings of audiovisual stimuli decrease with increasing source receiver distance but more gradually as compared to a break between the gallery seats and the rest of the hall (refer to Appendix 3.1.4 for Figure A3.2).

ASW and LEV ratings of the audiovisual stimuli appear to be very similar to each other; ANOVA shows no significant difference between the two sets of subjective responses (P=0.86), which raises the question of why subjects would perceive two different auditory spatial aspects so similarly. Refer to Appendix 3.1 for the complete statistical analyses relate to the results in this section.

5.4.2. Auditory Intimacy

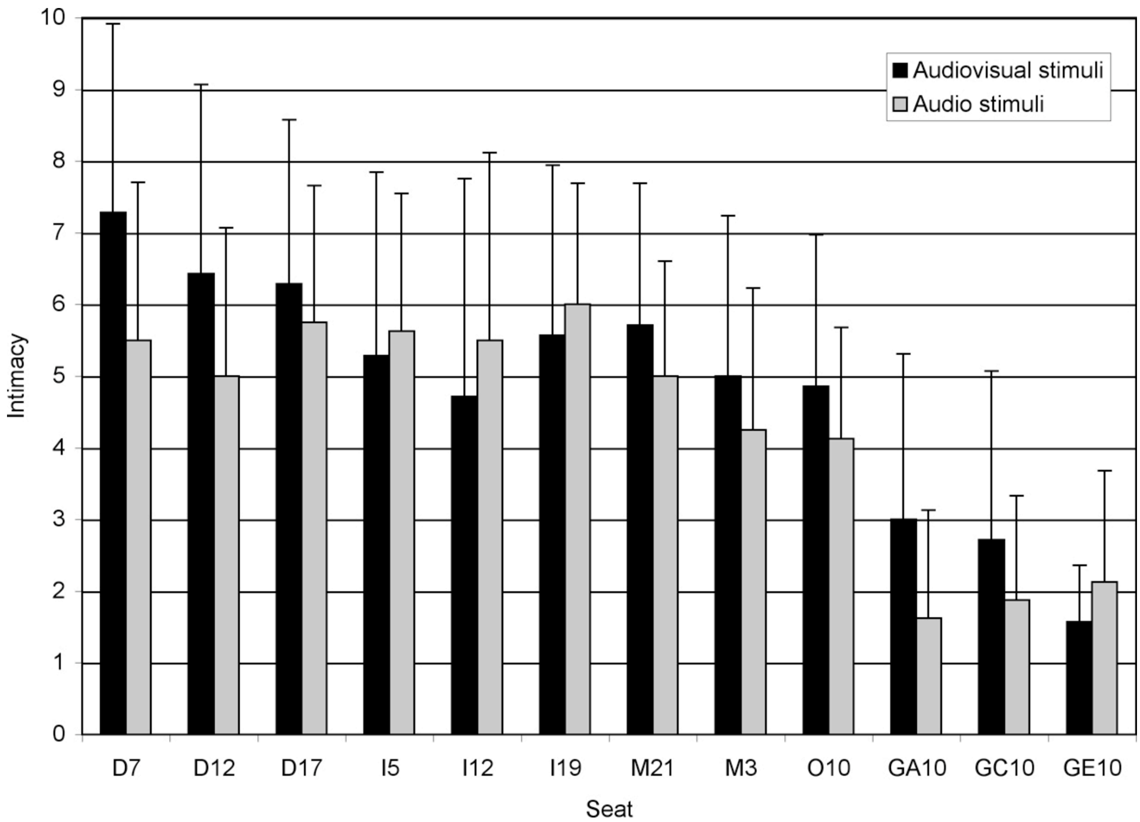

Figure 5.3: *Auditory Intimacy ratings*

Auditory intimacy ratings of audiovisual stimuli appear to be quite similar to those of audio stimuli. However, the ratings of audio stimuli for the gallery seats (GA10 to GE10 at 20 – 25m) appear to increase rather than decrease compared to the ratings of audiovisual stimuli. One unusual indication that seemed different for ASW and LEV is that the ratings of audiovisual stimuli appeared to decrease gradually from D7 to I12 then somewhat abruptly increase (with the difference of only about one point between seats I12 & M21), then decrease again. Despite the appearance of subtle differences between subjective responses of audiovisual and audio stimuli, ANOVA shows "test mode" has no significant effect on the ratings of auditory intimacy (P=0.18).

When analysing the audiovisual results separately, ANOVA shows seat locations to have a significant effect on audio intimacy (P=0.0003). Similar to the ASW and LEV ratings of audiovisual stimuli, auditory intimacy ratings of the gallery seats are markedly lower than all other seats. This would possibly be attributed to the noted differences in the sound level between the measurement points on the floor and those on the gallery. Refer to Appendix 3.2 for the complete statistical analyses relate to the results in this section.

5.4.3. Auditory and Visual Distance estimation:

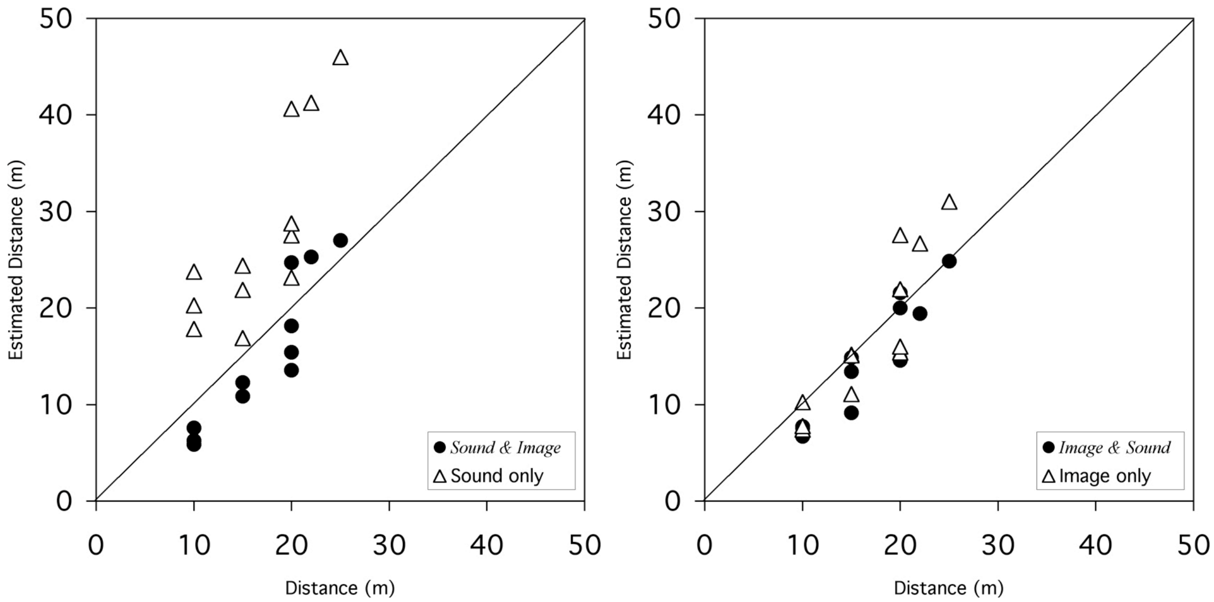

Figure 5.4: *Auditory visual distance estimation compared to audio stimuli (left), and visual distance estimation of audiovisual stimuli compared to visual stimuli (right).*

Results show auditory distance estimations of audiovisual stimuli are quite accurate - with a tendency for underestimation - compared to those of audio stimuli. It is perhaps obvious that subjects were relying on the visual stimuli to estimate distance, regardless of being asked to estimate auditory distance. ANOVA shows significant results for the ratio between perceived auditory to actual distance (P<0.0001).

The visual distance estimations of audiovisual stimuli are quite closely matched with those of visual stimuli, and both show tendencies for underestimation. Thus, ANOVA shows the "test mode" has no significant effect on visual distance estimation (P=0.05).

The overestimation of auditory distance in the audio-only experiment is significantly higher than the rest of the estimates. It also shows the large discrepancy between the distance estimates of the floor seats and the gallery seats in the audiovisual experiment. A possible explanation for this proportional similarity is that the subjects' detection of sound levels differences seemed to reinforce the overestimation and the gap between the floor and gallery distance estimates even though the subjects may have relied on the visual stimuli to estimate auditory distance. Refer to Appendix 3.3 for the complete statistical analyses relate to the results in this section.

5.4.4. Visual Intimacy and Envelopment

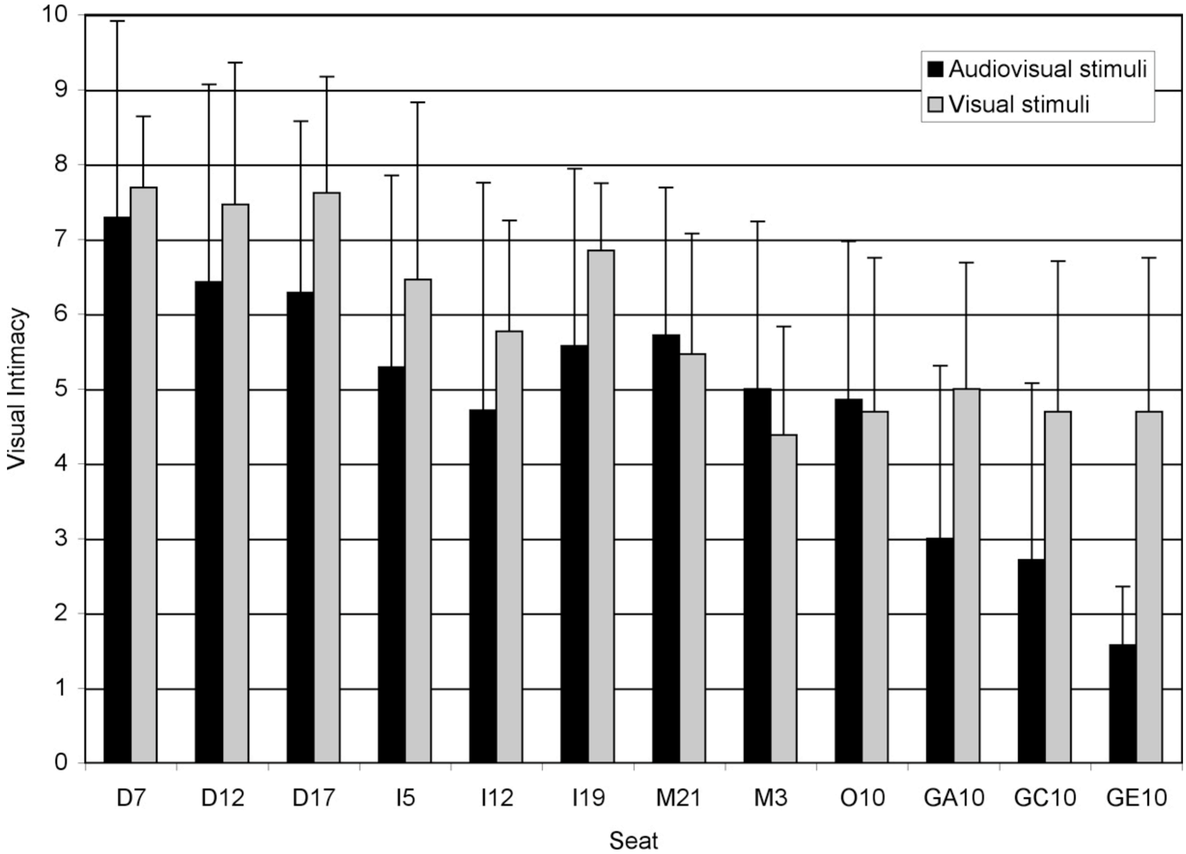

Figure 5.5: *Visual intimacy ratings of audiovisual stimuli compared with those of visual stimuli.*

The result shows visual Intimacy ratings of audiovisual stimuli are, on the average, one rating point lower than those of visual stimuli for the floor seats from D7 to O10. Although ratings of both audiovisual and visual stimuli decrease with increasing distance, the ratings of audiovisual stimuli appear to have a steeper slope compared to those of visual stimuli, especially from seats O10 (a floor seat at 20 m) to GE10 (furthest seat on Gallery at 25 m). As mentioned earlier regarding sound level differences and their possible influences on distance estimation, that effect is recurring here but to a significantly greater degree with visual intimacy ratings of audiovisual stimuli (for the gallery seats) significantly lower than those of visual stimuli. ANOVA shows “test mode” to have a significant effect on visual Intimacy ($P<0.0005$)

When analysing the audiovisual experiment separately, ANOVA (audiovisual stimuli) shows seat locations to have a significant effect on visual intimacy ($P<0.0001$).

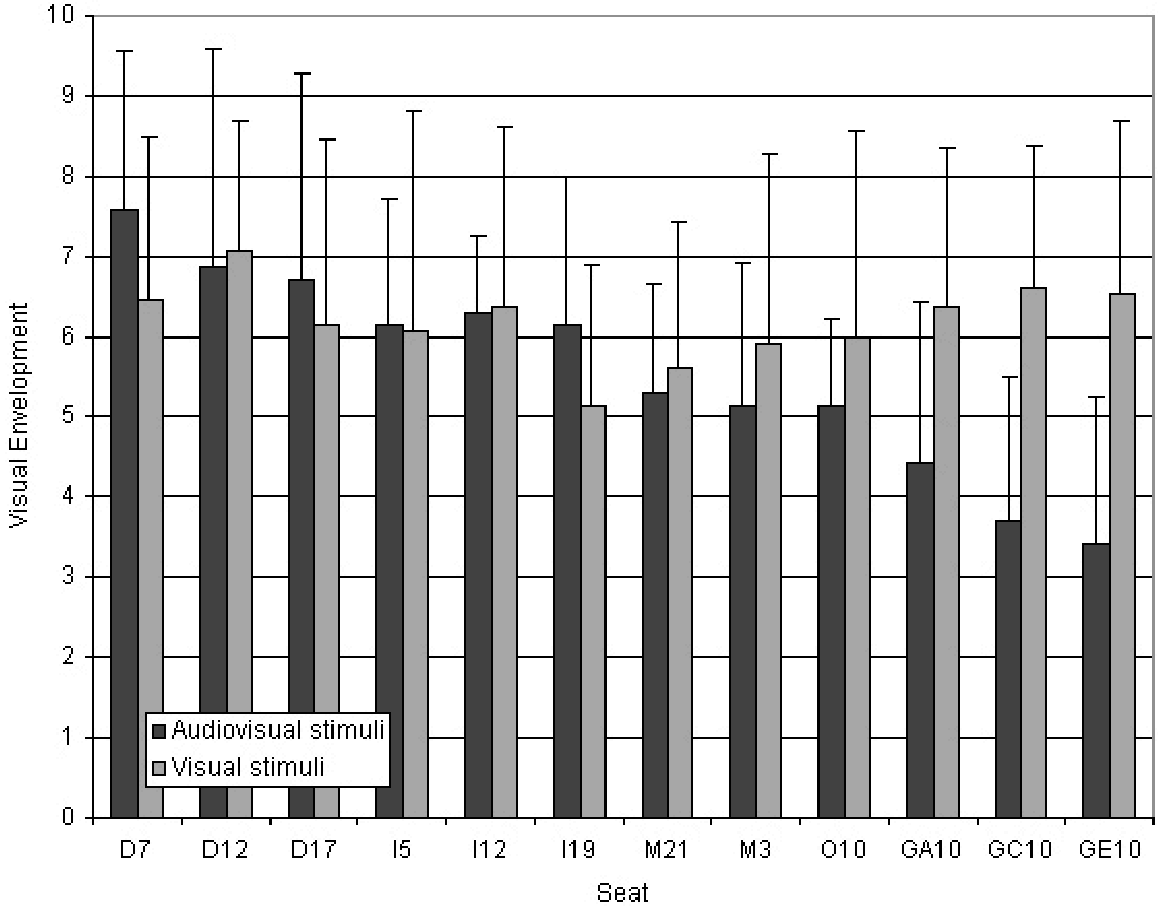

Figure 5.6: *Visual envelopment ratings of audiovisual stimuli compared to those of visual stimuli.*

For the visual-only experiment, unlike visual intimacy, envelopment ratings do not depend on increasing target distance. Overall, visual Envelopment ratings for audiovisual stimuli appear closely matched to those of visual stimuli for the floor seats (D7 to M3) then begin to significantly decrease reaching lowest rating at the furthest seat on the gallery (GE10). This is a similar phenomenon to visual intimacy, where there are significant negative discrepancies between audiovisual results as compared to the visual. Here, visual envelopment ratings of visual stimuli begin to increase with distance from seat I19 compared to the decreasing ratings of audiovisual stimuli. ANOVA shows "test mode" to have significant effect on visual Envelopment rating ($P=0.03$).

When analysing the audiovisual experiment results separately, ANOVA shows "seat" to have some significant effect on visual envelopment ($P=0.0011$). Refer to Appendix 3.4 for the complete statistical analyses relate to the results in this section.

5.4.5. Visual Spaciousness and Stage Dominance

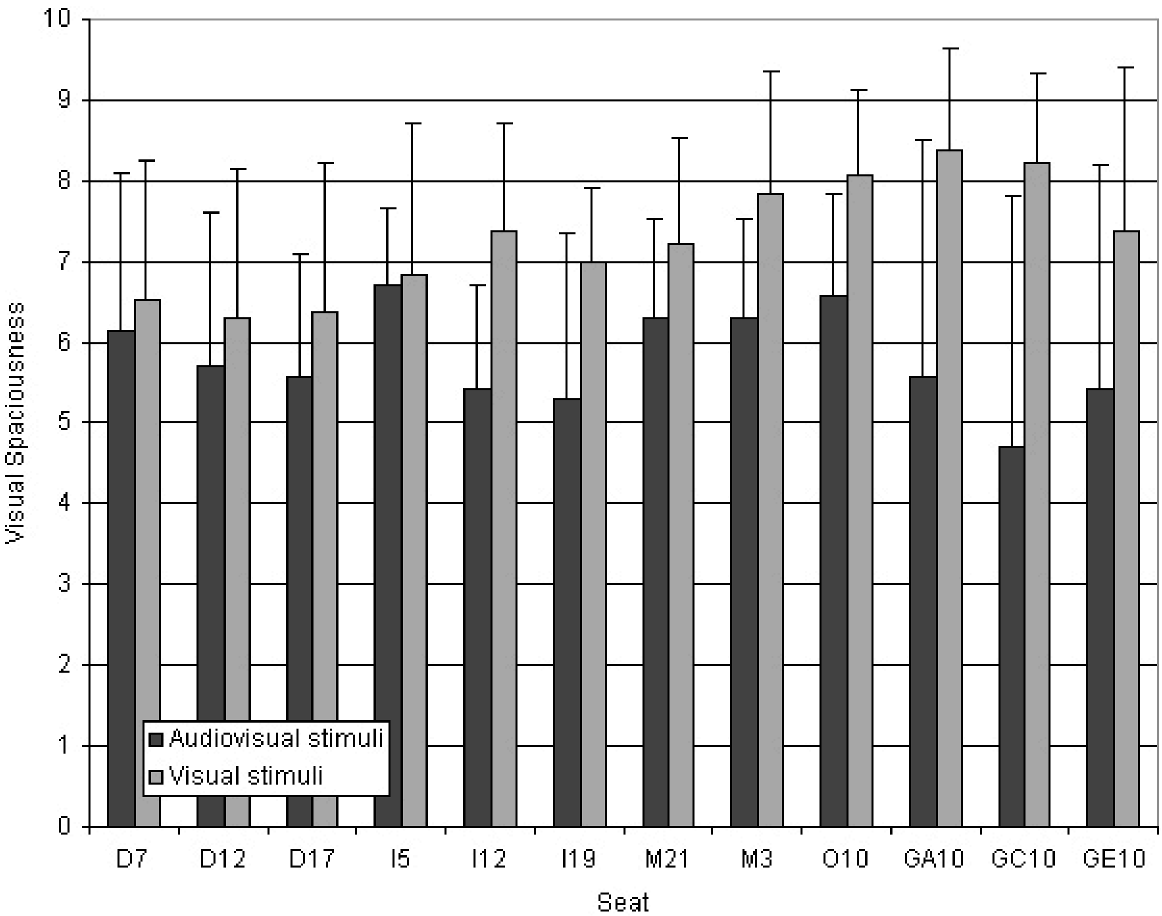

Figure 5.7: Visual spaciousness ratings of audiovisual stimuli compared to those of visual stimuli.

Figure 5.7 shows the visual Spaciousness ratings of audiovisual stimuli to be consistently lower than those of visual stimuli. Furthermore, the ratings of audiovisual stimuli seem to behave oppositely as compared to those of visual stimuli, especially seat O10 and the gallery seats (GA10 – GE10). ANOVA shows "test mode" has a significant effect on the visual spaciousness ratings (P<0.0001).

As visual Spaciousness relates to the volumetric sense of space, the audiovisual result shows the spaciousness rating increases as the target distance increases. When analysing the audiovisual results separately, ANOVA shows "seat" to have an insignificant effect on spaciousness (P=0.80).

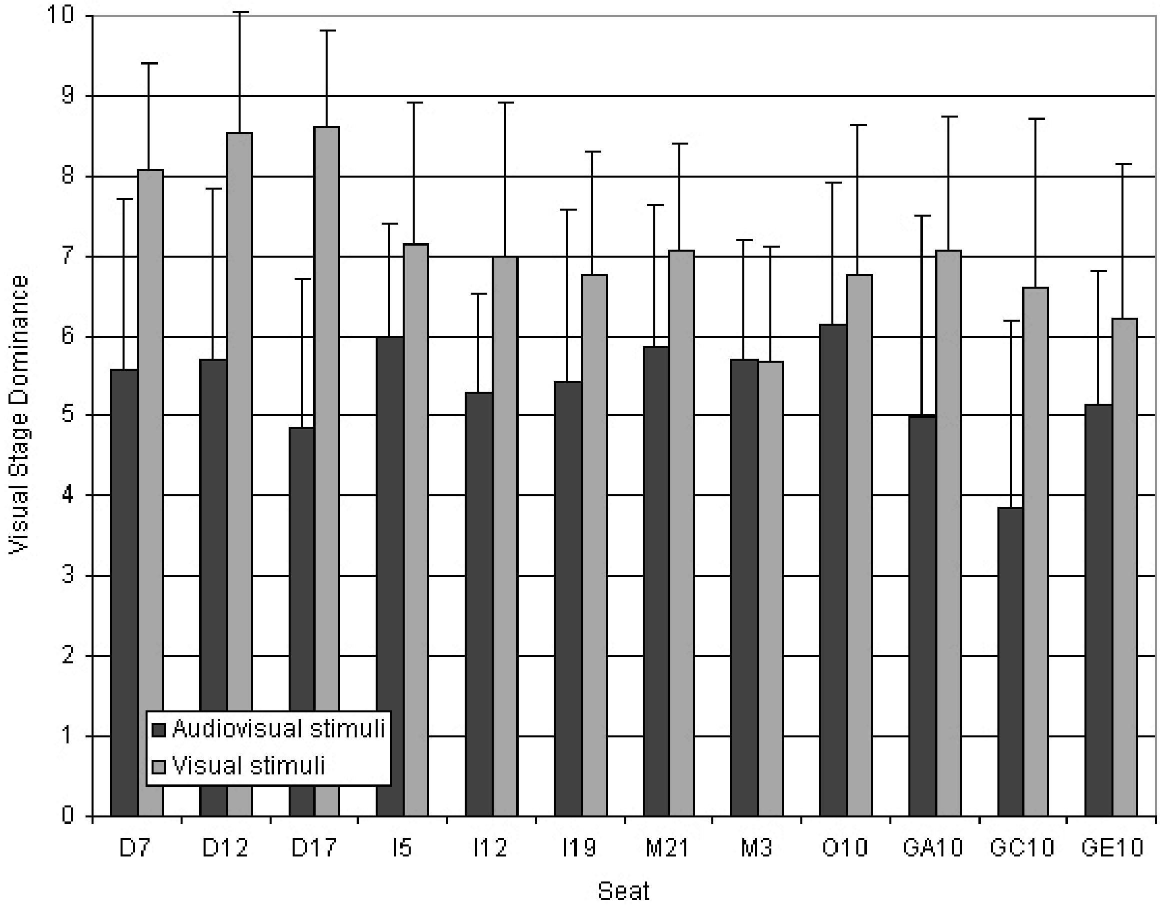

Figure 5.7: *Visual stage dominance ratings of audiovisual stimuli compared to those of visual stimuli.*

Overall, the visual Stage Dominance ratings of audiovisual stimuli are 1 to 3 points lower than those of visual stimuli. It appears that the ratings of stimuli from seat D7 to D17 are markedly different. The result once again shows a pattern of opposite responses between the audiovisual and visual experiment for the stimuli recorded on the gallery. Compared to all other visual ratings, Stage Dominance seems to suffer the greatest overall negative difference between audiovisual and visual results. This phenomenon appears to extend beyond the gallery seat stimuli to the rest of the hall. ANOVA shows "test mode" to have a significant effect on stage dominance (P<0.0001).

When analysing the audiovisual results separately, ANOVA shows "seat" to have non-significant effect on Stage Dominance (P=0.70). Similar to visual Intimacy, visual Stage Dominance ratings decrease as target distance increases (Appendix 4.5.4, Figure A3.3). Refer to Appendix 3.5 for the complete statistical analyses relate to the results in this section.

5.5. DISCUSSION

5.5.1. General

As with earlier studies discussed in previous chapters, there are clear limitations to this study since it is a replication of the earlier ones, except for the fact that it combines the audio with the visual. In doing so, it creates a new set of limitations.

The synchronisation of audio and visual stimuli may not have been properly presented to ensure both stimuli begin at exactly the same time. Since the subjects were allowed to control the proceeding of the stimuli, the time spent on one audiovisual sample, and the time gap generated by the out-of-sync between audio and visual stimuli would create unintended inconsistencies between each experiment session.

This experiment is an instrument for investigating audiovisual interaction, but it is a simplified representation of a real-world environment. Thus, the subjects are given the impression that they should somehow imagine that they are in an auditorium. However, there is the problem of audio and visual image-matching between the audio and visual stimuli. The photographs, taken of the stage, lack musicians and their instruments, yet the audio stimulus is an orchestral recording.

The author has considered presenting a simulation using video for this experiment. However, the logistics and time involved in making a video would create additional problems, which may adversely affect the outcome of the experiment. The most significant problem involves the available audio recording technology needed to make usable moving picture and audio recording compare to what the author has access to. It is important to match the movement of the HATS (head and torso stimulator) to the moving picture. In this case, it would be difficult to create an accurate rendition of the sound recorded in an auditorium when the HATS available to the author is a stationary one. Furthermore, a moving picture is inconsistent with the scope of this particular research as the author's initial interest in the instances of stationary impression of sound and spaces rather than a continuous impression caused by moving about a space.

Because the experiment uses only one auditorium, the result cannot be generalised. However, the previous study shows, when analysing audio and visual spatial impressions separately, that subjective responses are behaving both similarly and differently between auditoria. Despite these and other limitations, the study does yield results that confirm the usefulness of further investigation into audiovisual interaction in auditoria designs.

5.5.2. Audiovisual interaction in spatial impression

The overall difference between visual spatial impression ratings of audiovisual stimuli and visual stimuli is due to the possibility of auditory distraction. The possible cause for this subjective phenomenon is the nature of music-listening in concert halls, where concert hall audiences are mostly focussing on the music more than on the architecture of the hall. Therefore, a subject has to shift focus and make a conscious effort when being asked questions relating to what they are seeing. Thus, the sound becomes a distraction.

It is possible that the auditory dominance in symphonic music-listening is also the cause for the non-significant difference between ratings of audiovisual and audio stimuli. The visual part of the audiovisual stimulus becomes secondary, thus non-distractive, as subjects are focussing on judging the audio stimulus.

The markedly consistent discrepancy between the audiovisual ratings of the gallery seats, compared to those of visual-only ratings, may be caused by an effect associated with the questionable quality of the audio stimuli for the gallery seats. The following section (5.5.3) will discuss the issues related to the sound quality of audio stimuli. This raises an interesting question, whether the nature of music-listening in concert halls is the sole cause of the negative effect that audio stimuli have on the visual spatial impression.

5.5.3. Audiovisual Spatial Impression variations

All subjective results show that auditory intimacy decreases with distance. However, this present study shows significant discrepancies between the ratings of the floor seat stimuli compared to those of the gallery seats. To confirm whether this discrepancy has occurred, due to this particular group of subjects or to the quality of the impulse responses, the comparison between this and the previous measurements session[3] is needed. There are several reasons for comparing impulse responses between the two recording sessions, different loud speakers, and the possibility of incorrect recalibration of HATS for the gallery measurement.

[3] There are two separate measurement sessions conducted in Hall C. The first used seats only on the main floor and not the gallery. The impulse response measured in this session was used in the experiment discussed in Chapter 4. The purposes for the second one are to complete the gallery measurement used for the experiment in this chapter, and to match Hall A's sound source for future comparison of impulse responses.

The comparison of the impulse responses would now be even more necessary in light of the results. However, comparing sound level differences between measuring sessions is not possible due to one session with an incomplete number of positions. In the analysis of the audiovisual and audio-only result, when comparing seats, ASW, LEV, and Intimacy, all behave similarly.

Varying seat locations appeared to be the primary cause for the variation in audiovisual spatial impression in Hall C. As discussed above, the questionable measured impulse response may be a secondary cause for the discrepancy between the floor's ratings and the gallery ratings.

5.6. CONCLUSION

The previous chapters explore the visual counterparts to auditory spatial impression and discuss the degree of correspondence between the two. Space perception in vision and audition interact differently with the physical environment, thus the degree of correspondence would be varied and the relationship between auditory and spatial impression are both necessary and arbitrary. Perhaps this is the precedence for the varying degree of audiovisual interaction among the senses. Consistent with the previous findings in this thesis, physical distance is seen as a predictor for both auditory and visual spatial impression while other parameters are not as consistent.

The analysis of the audiovisual results in the present study consider the effect of seating location on spatial impression and find significant variation of both auditory and visual spatial impression. The variation is especially large between the ratings of floor seats and gallery seats. It appears that seating location (in relation to distance) could be considered a fair predictor for spatial impression.

One of the goals in acoustical design objective for a concert hall could be to provide acoustical quality, which is as consistent as possible in all area of seatings. However, this may not the case in the present study of Hall C. Perhaps the visual aspect could be designed to serve as compensation to the acoustical shortcoming.

It is apparent that the participants in this study had prior training of music-listening in symphonic concert performance. As the results show in this chapter, perhaps this training is a possible cause of the insignificant differences between the ratings of audiovisual and audio stimuli. Subjective tests have their limitations, as do tests using prior-trained subjects. Thus, it is apparent that in a symphonic music performance in a concert hall, audition is a dominating sense and vision plays only a supportive role.