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ACOUSTICAL INTIMACY IN CONCERT HALLS: DOES VISUAL INPUT AFFECT THE AURAL EXPERIENCE?

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1 INTRODUCTION

Of the major acoustical attributes describing the perception of music in concert halls, acoustical or auditory intimacy (herein referred to as Intimacy) is the least understood in terms of its objective sound field correlates. The purpose of this investigation is to determine the factors which relate to overall acoustical quality in halls, and to provide a better understanding as to what Intimacy is, and how it is related to other factors.

The goal of this paper is therefore to determine the objective factors which contribute to the perception of Intimacy, particularly where applied to larger concert and opera house venues. These factors are of course physical in nature including dimensional and relational characteristics of enclosed spaces in addition to the objective measures of the sound field. The first questions to be asked are "what exactly is Intimacy and what room design features contribute to it?"

The past two decades have seen the development of the digital computer and the resultant ability to take objective measurements in concert halls. These data over a multitude of halls have been studied and correlated with the subjective qualities and factors associated with them, and have been reported extensively in the literature. The most prominent collection of information along these lines are in the books by Beranek[1] and Barron[2] which reference the many studies such as those at Göttingen[3] and Berlin[4]. A comprehensive summary of the development of acoustical objective and subjective factors can be found in the tutorial paper by Beranek[5] published in JASA in 1992.

2 INTIMACY AS A CONCEPT

2.1 Subjective Acoustical Factors and Common Experience

Subjective factors which have been determined relevant to the perception of music in concert halls include Reverberance, Loudness, Clarity, Spatial Impression, Intimacy and Warmth. There are of course many other acoustical descriptors such as Texture, Balance, Blend, Ensemble and so on.

These acoustical words and concepts relate in varying degrees to our common experience as listeners in concert halls. Take the judgment of Reverberance for instance; this is a readily understood concept for most people. Another generally understood acoustical term is that of Loudness, a concept common to virtually everyone's daily experience. Evaluation of the relative value of these factors in a concert hall would rather easily be made by listeners asked to make such judgments.

Intimacy, on the other hand, does not lend itself readily to interpretation, especially by those not experienced in the realm of critical listening in concert halls or other acoustical environments. Whereas reverberance and loudness are somewhat singular in their experience, Intimacy is surely multidimensional in character in that it is more of a feeling, comprised of a combination of concepts relating what we hear to the perception of the space surrounding the performance and indeed to the observation of the performance itself.

Another way to express its complexity is to say that Intimacy is probably not an independent or orthogonal subjective attribute. Rather, as has been reported by Kahle,[6] it may be a dependent factor which is strongly correlated with other subjective factors. Another practical example showing the complex nature of Intimacy is the finding of the author through conducting listening tests that the average, inexperienced listener doesn't really know what Intimacy means relative to music and finds it difficult to define.

2.2 Defining Intimacy and its Acoustical Origins

The Intimacy referred to in this paper applies to the audience experience as relating to a performance on stage. This is as opposed to the issue of Intimacy for the performer which is the space as experienced on stage relative to the response of the local and larger room environment (see Section 6 for a brief discussion of performer Intimacy issues).

The traditional definitions of "intimate" point to the difficulty of applying the term to an actual dynamic, physical experience involving the perception of the performance of music; these definitions include, "private or personal, closely associated, familiar." There are few published references to Intimacy in the listening context prior to Beranek's[7] seminal work on acoustical design and quality in 1962 where he said that "a hall has Intimacy if music in it sounds as though it is being played in a small room." He also said that an intimate hall has "presence." Several references relate Intimacy to the perception of the size of the room, whereas others refer to feeling close to the action.

Barron[2] has defined Intimacy to "one's degree of identification with the performance, whether one feels acoustically involved or detached from it." Beranek[8] selected the term Intimacy to "characterize the listening attribute of closeness of communication between the listener and the orchestra" or other source of music.

The origin of intimate sound comes from a few centuries ago when music was performed by small groups of musicians for people in small rooms. In most cases, the attendees knew each other or at the least where known to the patron providing the entertainment. The setting was by definition "intimate" and the term conjures the feeling of the small size of the performance space and therefore the sound field which exists therein.

2.3 Intimacy and the Acoustics of Small Spaces

The acoustical characteristics of small rooms are well known through listening experience and room acoustic measurements. Chamber music was written with the small and intimate setting of the room and the audience in mind. The properties of such spaces which contribute to the overall setting and intimate experience include:

- Proximity to the Performer – This is signified by a relatively high direct sound level, with a short time delay between the movement of the performer and the arrival of the direct and early sound. This sound is reinforced by the visual proximity to the source.
- Loudness – A high value of sound strength due to a small room constant and strong early reflections.
- Reverberance – A relatively high value for the usually smaller room volumes involved due to the use of hard surfaces and little inherent absorption.
- Proximity to the Room's Boundaries – This creates a visual context which relates to high values of early reflections and strong lateral reflections.
- Architectural Diffusion – Such rooms generally have well articulated surfaces, coffered ceilings, statuary and other architectural artifacts which provide a high degree of diffusion and "texture" to the sound experience.
- Acoustical Brilliance – The nature of smaller rooms of the chamber period is that the treble frequencies are accentuated with a noted lack of warmth from the low tones.

Comparison of impulse responses between small and large performing spaces illustrates the above properties. With a standard source signal, an impulse will be stronger and will show a dense pattern of early energy in the smaller room.

2.4 Survey of Acousticians on Defining Intimacy

2.41 Results of Intimacy Definition Survey of Acousticians

A survey of acousticians from around the world with experience in visiting, evaluating and designing concert halls has yielded interesting comments and opinions as to the meaning of Intimacy. 85% of respondents listed "closeness to the performer" as their definition of Intimacy. The next most common definitions related to "as being in the same room" and "the room sounding smaller." Other descriptions included feeling: "Immersed in the music," "being drawn in to the performance," "a connection with the performer," "at home," and "that the performer is playing for you."

2.42 Objective Acoustical Factors Derived from Survey Descriptors

When applying the listening experience to a large space, the perception of closeness or proximity to the source can be related to several objective parameters as discussed in Section 2.3. The most obvious factor is that closeness is primarily perceived visually, through observation of the space, even before the acoustical event begins. And, since the relative strength of the direct sound is immutable, the strength of the early reflections, and overall total sound strength of the room are the factors which can hope to contribute to the feeling of "closeness to the performer." These same physical attributes also relate to the room sounding smaller than it actually is. The perception of "immersion" in the sound can be related to both the degree of lateral energy provided along with the sense of reverberation.

2.5 Acoustical Factors Relating to Intimacy from the Literature

Over the past decade, Intimacy has tended to become synonymous with the factor "initial-time-delay gap" or ITDG. This is the *de facto* definition stated by Beranek in his publications with the further comment that Intimacy also relates to "loudness of the overall sound since the listener assumes that a performance sounds louder in a small room than in a large one."[9]. While ITDG isn't technically defined in the literature, Beranek defines it as "the time between the arrival of the direct sound from the stage to the arrival of the first reflection at a measuring point."[10] This measuring point is stated as being a position near the center of the main floor.[11] Preferred ITDG values are stated to be at ≤ 20 msec., and in general, the shorter the time delay gap, the more intimate the experience.[1,5]

Other researchers aren't in agreement with IDTG being a strong factor, let alone being the sole major factor. Ando's[12] experiments found the preferred IDTG was related to the autocorrelation function (ACF) of the music being played in the judgment experiments, and these values are significantly greater than 20 msec. He also found that this first reflection is not important if it's not the strongest reflection. A discussion on the differences between Ando's simulator findings and Beranek's experiential findings can be found in Beranek's paper.[13]

In a study of early sound field changes in auditoria, Cox et al.[14] tested subjects' ability to perceive the differences in the sound field by altering the ITDG and found that the differences of arrival time of the first reflection have a negligible effect on perception of the sound field.

Barron's studies[15,16] find that the perception of loudness is directly correlated with the objective sound strength, and that Intimacy is best correlated to the total sound level. His results found no correlation between ITDG and subjective Intimacy.

Correlating room acoustic measurements with listening experience in specific rooms, both Hyde[17,18,19,20] and Toyota, et al.[21] have reported that seats with high levels of early energy are reported to be more intimate independent of the distance from the source. Toyota's reflected energy cumulative curves (RECC)[21,22] show the buildup of reflected sound energy over the first 160 msec. in a large concert hall and indicate that the rank order of total sound level G between seats is determined by the early reflections occurring within the first 80 msec. The seats with the greatest early reflected energy and total sound level are rated by listeners as being the most intimate.

The contribution of the early sound field to Intimacy has been reported by Lavandier et al.[23] in a study where subjects rate reverberant spaces as "remote" whereas when the sound field becomes less reverberant, C80 increases and the sound is perceived as being "distinct." As C80 increases further, the "clarity effect" changes to a feeling of "proximity," with the perception of the source being more "nearby." High C80 of course can mean the existence of high early reflections.

Kahle's[24] survey of the subjective factors in concert halls has yielded some interesting results on subjective correlates with Intimacy. His work has found a strong positive correlation with subjective loudness as well as an independent correlation with low frequency subjective loudness "clearly indicating that there is a link between bass frequencies and the question of Intimacy." He also has found a strong correlation with what he calls "Contrast" or the definition of attacks in the music. In other words Intimacy is positively correlated with "a strong emergence of useful temporal intervals in the room response."[6] This is linked to objective distance meaning that the closer we get to the source, the greater the Contrast, and the more intimate it sounds. Finally, Kahle found no correlation of Intimacy with subjective reverberance and subjective loudness at high frequencies.[6]

2.6 Survey of Acousticians on Objective Factors Relating to Intimacy

Results of the same questionnaire of acousticians on the objective components of Intimacy are summarized in Fig.1. On a scale of 1 to 10, respondents were asked to rate the objective factors they believe are correlated with the perception of Intimacy, with 1 indicating "not correlated" and 10 indicating "highly correlated." Each rating was to be an opinion based upon each respondent's personal listening experience. Average opinion of highest correlations were found to be direct Level and source-receiver distance, G80, room width, shape and dynamic visual input, which is partially linked to distance from the source. All factors but EDT, ceiling height and RT received a rating of 5 or greater. It appears that Intimacy may be broadly dependent upon many objective factors. Of interest as the major topic of this paper is whether the visual aspects of a space have an influence on how Intimacy is perceived.

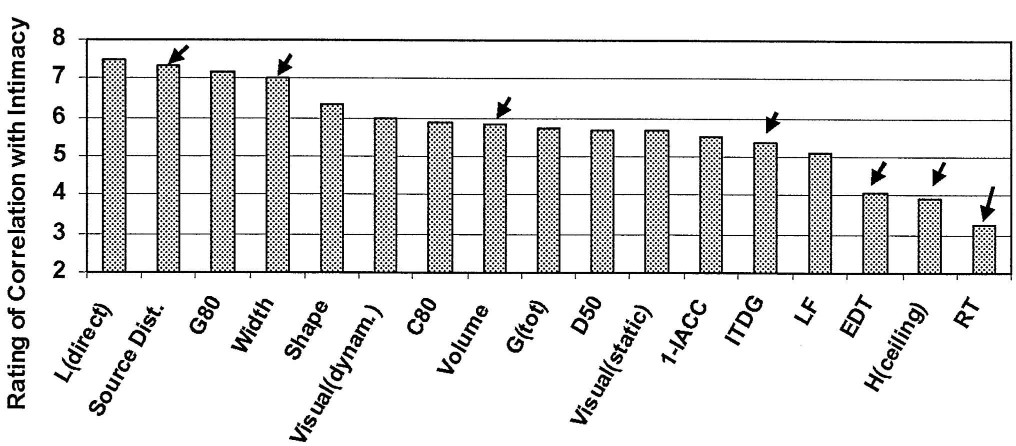

Figure 1 – Summary of opinion on correlation of objective factors with Intimacy. The arrows indicate an inverse correlation.

2.7 Summary of Results Pointing to Objective Factors of Intimacy

From the definitions of Intimacy, the literature and survey of acousticians of Sections 2.4, 2.5 and 2.6, a pattern of related objective correlates to Intimacy is presented. To summarize, these are:

- Strength of the direct sound (inversely proportional to source-receiver distance)
- Strength of the early reflections
- Strength of the total sound
- Degree of lateral energy
- Degree of immersion in the reverberant sound
- Visual input – both static and dynamic cues

Clearly, all factors can be related to the size of a room with smaller being more intimate. For designers of large concert halls, the issue at hand is how these factors are achieved through architectural design. Since the strength of the direct sound can't be manipulated naturally, the perception of "proximity to the source" must be achieved through architectural means. It should be noted that the degree of both lateral energy and immersion in the reverberant sound is almost purely related to room design and somewhat to each other. The late energy contributing to "immersion" surrounds the listener in seating planes which are not steep, allowing a diffuse field to be incident from the sides and back.

3. CONCERT HALL SURVEY POINTS TO VISUAL INFLUENCE ON WHAT WE HEAR

Barron's[15,16] extensive survey of British concert halls undertaken in the 1980s reported the combining of both objective acoustic measurements with the subjective evaluation of the same spaces during live concert conditions. The study found three independent factors to be correlated with "overall acoustic impression" as being "Reverberance," "Envelopment" and "Intimacy," and importantly found a correlation between Intimacy and subjective loudness. Since Intimacy was also found to be directly correlated with total sound level G_{tot}, the connection between Intimacy and distance (a visual impression) is strongly suggested.

Most interesting from these studies is the finding of relationships between sound strength, Intimacy and the perception of distance and size of the space. Barron found[25] that subjective loudness was directly related to total sound level (G_{tot}) and to the source-receiver distance (r) by the general relationship

$$\text{Loudness} = k\,(G_{tot} + 0.076\,r) + K \qquad (1)$$

where k and K are scaling constants and the loudness units are arbitrary. What is surprising here is that distance term is positive meaning that a sound of the same objective level is perceived as louder for a listener farther from the source. The net result is that this loudness perception increase with distance compensates for the natural drop-off in level G over distance thus giving the perception of constant loudness with distance. Somehow, the visual change with distance causes the listener to compensate for the drop in objective sound level. With the level drop-off rate and the distance compensation rate (coefficient of r) being similar, Barron summarizes "This leads to the conclusion that listeners may have a subjective expectation of loudness based on typical average behavior in concert halls (revised theory) and respond if loudness is louder or quieter than expectations."[26] "Expectations" in this case refers to what is anticipated on the basis of visual perception of the location of the listener relative to the source and to the space in general.

An example of this phenomenon has been given by Hyde[18,19] in the case of Segerstrom Hall in Orange County California. Measurements in the back of each of the four seating sections show levels of G significantly greater than the expected "revised theory" values found for the space in general. These greater levels occur due to the acoustical design of the hall. With objective levels being the same value for two seats, the seat which is farther from the source is found to be subjectively louder. Further discussion of this situation can be found in Barron.[26]

When the farther seat has the same level G as a closer seat, it is also judged to be more intimate. It appears that that the compensation in perception of level due to visual input has a related effect on the perception of Intimacy. Since sound strength G and Intimacy are found to be directly linked, this result is not surprising.

4 MULTISENSORY INTEGRATON – AUDITORY & VISUAL INPUT

4.1 Perceptual Phenomena and Psychology of the Integrated Experience

All experience is fundamentally multisensory. That is, we have evolved as a species by integrating converging sensory input in order for the information and input to make the most sense and be the least ambiguous. The product of these integrative processes is "perception."[27]

There are significant differences between "seeing" and "hearing" as opposed to the perception of an event which uses both senses. Generally, the visual modality predominates. Where the intensities of stimuli are similar, the visual effect on aural perception is greater than the effect of sound on visual perception. The ventriloquism effect is a well known example.

Since sensory systems have evolved to work together, the synergy between auditory and visual systems are generally evident in our experience. One common example is the perception of speech in a noisy room. Visual cues significantly enhance the processing of auditory inputs providing the functional equivalent of altering the signal-to-noise ratio of the stimulus by up to 15 to 20 dB[28] depending on the "stimulus set" and context of the information (for instance, if the words and phrases are commonly known to the listener). The extreme of this processing example is that of lip-reading, where there is no aural signal, yet the information is transmitted and perceived via visual stimulation. Further to this, MRI brain studies[29] show that the sight of lip movement alone actually stimulates activity in the auditory cortex.

There are many examples in cognition psychology where seeing a source actually affects what we perceive we hear; in other words, with visual input the brain process actually alters the perceived frequency content of the source. A well known example of this is the McGurk effect[30,31] where one "hears" a speech signal with their eyes closed but, with visual input of the speaker's lips forming another sound one perceives a third sound, not the same as what they "heard." The brain's multisensory integration system actually modifies the signal of the aural input. This is a palpable example of receiving one signal yet "hearing" a different event depending upon what one sees. One would expect that this sort of sensory input integration would happen in the concert hall context where the visual aspects of the event are of similar intensity as the aural.

4.2 Perceptual Aspects of the Concert Hall Experience

To acousticians, the aural experience is generally the singular issue of concern in the evaluation and study of performing spaces and indeed in their enjoyment as well. Of course, attending a concert or opera is entirely a multisensory experience and the visual aspects of it are hypothesized as being very important, even relevant to the evaluation of overall acoustical quality. Beyond visual stimuli, even aspects of comfort and the ease of moving about enter into the overall experience.

Visual input in the performance space context is comprised of both static and dynamic queues. Visual static input relates to the perception of the room's boundaries, their size and orientation, lighting, texture and color, the framing of the performance area and, to the individual, the physical relationship of the observer to the boundaries as well as relationship with the performance including distance, degree of elevation, and degree off the room's axis.

Visual dynamic input relates to the movement of the performer including the conductor, the synchronicity of movement and cadence of string and other players and the movement and expression of the soloist. The degree to which an observer integrates and uses this information clearly depends on the amplitude of movement and the size of the dynamic image which is inversely related to distance.

Indeed, it can be argued that it is the magnitude of the visual input relating the source-receiver distance that determines the amount of "information" and magnitude of the experience transferred to the observer. As with speech, music is produced in rhythmic patterns often with a low frequency modulation spectrum of about 4 to 5 Hz, corresponding to articulation peaks on the order of 200 msec. The observer's degree of exposure to the cadence, magnitude of movement, even the location of actual instruments which produce the different sounds, may be said to enhance the experience by adding visual information coherent with the acoustical field. It is hypothesized here that this distance related effect of dynamic visual input is closely related to the concept of Intimacy on the basis that source-receiver distance is a bimodal factor.

Both static and dynamic visual stimuli relate to distances and boundaries and therefore to major architecturally important issues producing the acoustical field. For instance, the fundamental issues of size and volume of the enclosure determine acoustical properties such as the direct sound level, early sound field, and reverberation time. Further design related acoustical properties include sound strength G through the room constant (highly dependent on the number of seats), and the degree and direction of early reflections and late reflections.

4.3 Physiological Explanation for Integration of Auditory and Visual Stimuli and Application to Intimacy in Small and Large Rooms

It's not surprising that there exists a natural cooperative interaction among auditory and visual sensory systems in the brain's wiring. The result of this synergy is an increase of the overall reaction speed of processing signals, and the increase in magnitude of the evoked potential of the combined auditory and visual signal in the brain.

Reaction times for visual and auditory input are found to be in concordance with the intimate setting of the chamber music experience. It is found that reaction to an auditory stimulus is faster than to a visual stimulus, the difference being on the order of from 40 to 60 msec. due to the longer processing time of the retina as compared to the inner ear.[27] Therefore, when a visual stimulus precedes an auditory stimulus by the difference in their processing times, the two inputs converge simultaneously and are coherent. The result is that the reaction time to the combined stimuli becomes significantly shorter; at the same time, the amplitude of the evoked potential or neural drive of the combined stimuli is significantly greater than it would be to either stimulus alone. This amplitude increase for the combined stimulus event (auditory and visual) is analogous to an increase in the magnitude (and one would presume of the quality and satisfaction) of the experience itself.

The shortened reaction time affects the efficacy of producing and amplifying information since generally one doesn't need to know the whole signal in order to understand it. We are therefore capable of understanding the first signal before the second signal comes along, ensuring more complete processing of the event.[32] In summary, more neural drive and shorter response time work together to create a more intense and complete experience. The combination of auditory and visual stimuli therefore affect the perception of the event itself. A final comment which relates to the sensory experience in concert halls is that the greater the intensity of a stimulus, even if independent of another (magnitude of the visual related to distance, or magnitude of the auditory input in general) the greater the reaction time and amplitude even for that stimulus alone.

Application of the above discussion to the listening experience in halls is tempting. The processing delay phenomenon between the eyes and ears indicates the maximum experience will occur at listener distances of from around 10 to 17 meters from the performer. A performing space with the audience within the greater distance could easily have around 400 to 600 seats. It could be argued that for the greater distances of larger spaces, increased intensity of auditory input be used to make up for the time alignment mismatch which occurs between visual and auditory inputs. This argument supports the idea that greater early energy in a room's design reinforces the effects of the direct sound level and that a greater sound level reinforces the same experience commensurate with a smaller room.

4.4 Acoustical Studies Indicating Visual Influence on Aural Perception

There is evidence in the literature beyond perception psychology experiments that the perceptual modalities of seeing and hearing interact and reinforce one another in a complex relationship. Toole and Olive have published a number of papers on the perception of music, primarily through electronic systems involving loudspeakers, microphones and different listening environments. In one double blind experiment,[33] the quality of different loudspeakers was tested with the primary variable being whether the listener knew the loudspeaker's manufacturer and its retail price. It was found that such knowledge was the major determinant of quality, with listeners being less responsive to audible differences and therefore more responsive to their biases. The degree of bias was also found to be greater when the difference between test sources was small. There are obvious parallels with concert hall listening, one being that visual input from the hall itself (both aesthetic as well as distance related) can affect the judgment of perception of the hall's acoustical quality in addition to other biases relating to the hall's reputation, or the reputation of the performer/orchestra for that matter. Where the acoustical difference between halls is great, effects of bias may be less dominant.

Woszczyk et al.[34] report work on the matching of auditory and visual information and how their cooperative interaction reinforces human awareness of the stimulus. This matching of bimodal data is found to "trigger perceptual synergy between modalities and promote inter-modal fusion." The visual input "reduces the ambiguity of sound and helps to define its purpose."[35] They report matching factors important for a synergetic perceptual interaction between the auditory and visual. Those relating to the concert hall experience include "temporal and spatial coincidence," "congruence of auditory input with visual movement," and "balance between image size and the loudness of sound." The importance of these factors is emphasized when formulating or conducting listening tests relative to the concert hall experience. They also cite work[36] showing that improved visual input has a similar effect on the perceived quality of the sound for the same event. This again reinforces the connection between the two modalities and the role of distance in the perception of Intimacy and overall sound quality.

A study by Larsson et al.[37] at Chalmers University applies the auditory-visual matching principles of Woszczyk[34] to bimodal virtual environments for the purpose of developing accurate electronic acoustical test simulation. Their findings point to work by Storms[38] who found that subjective properties such as auditory source width, source-receiver distance and perceived room size are highly influenced by visual information concerning the room. A summary of their findings includes: **Perceived Reverberation Time (PRT)** was found to be affected by visual input; it was greater in the absence of visual information, **Auditory Room Size** was found to be related to **PRT** and was affected by visual information, **Perceived Source-Receiver Distance** was rated as being greater (more distant) in the absence of visual input, and **Auditory Source Width** was found to be influenced by visual information. They also found that the type of signal (orchestral motif, solo instrumentalist, vocalist) affected the results. To summarize, visual stimuli were found to be a significant determinant of the acoustical perception of a space, and need to be taken into account in subjective testing.

4.5 Survey of Opinions on Auditory-Visual Aspects of the Concert Hall Experience

In the same survey reported above acousticians were asked to give their opinions as to whether the visual relationship between the listener, room and the performance affects the perception of certain acoustical factors. Figure 2 shows the results of this survey of prevailing opinion, where there is near unanimity that Intimacy is "definitely" influenced by visual stimuli. All acoustical factors in Fig. 2 except reverberation are thought to at least "perhaps" be influenced by visual input by over 70% of the respondents. Several respondents felt that all factors were visually influenced with one researcher knowledgeable in the field remarking "humans are multimodal receivers." Second to Intimacy itself, "overall acoustical quality" was considered to be highly influenced by visual stimuli.

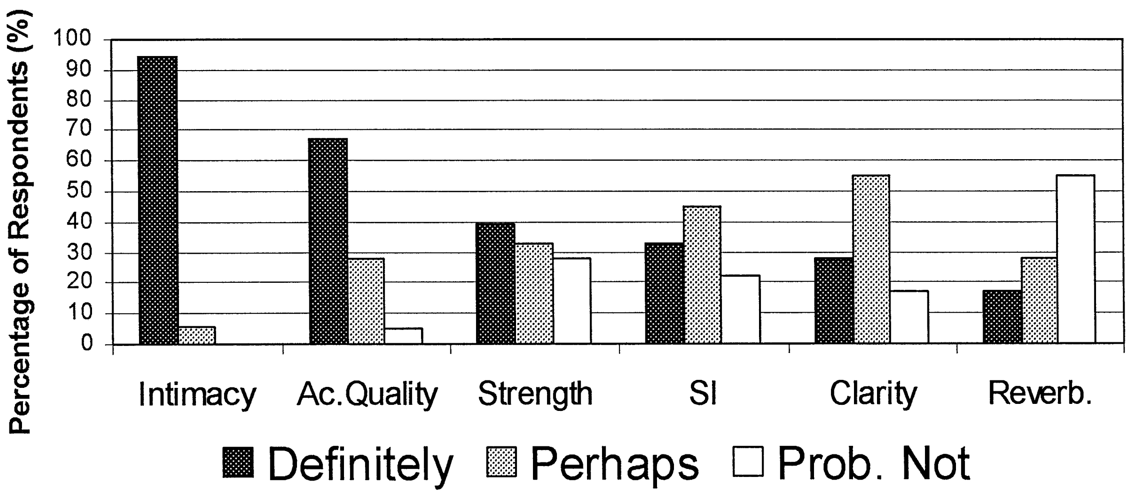

Figure 2 – Opinion survey of visual influence on sound field perception. (SI = Spatial Impression)

5 TESTS FOR LOUDNESS AND INTIMACY IN 500 SEAT RECITAL HALL

Listening tests using various music motifs were undertaken by the author in a 500 seat shoebox recital hall in which objective acoustical measurements at the listening positions were taken, as shown in Figure 3. Two seats were used, Position A at the front of the room near the stage, and Position B at twice the distance as Position A from the source, near the rear of the hall. Subjects were exposed to short passages of anechoic music (four motifs) at Positions A and B without any adjustments to level, such that the natural drop-off of sound strength G in the space is maintained. Subjects at Position B were additionally exposed to the same level as at Position A (called Event B+) by adding two delays of 20 and 55 msec. which were 25° (left) and 40° (right) off axis respectively. To complete the visual setting, a photo of a chamber ensemble on a stage was projected on a large screen on the hall's stage at the location of the central speaker. Sound levels between 67 and 76 dBA were used as appropriate for the type of music chosen and the reverberant conditions of the test recital hall.

The subjects were not considered to be "experienced" listeners with music and performance for most not being a part of their everyday lives. They were exposed to the sound fields in various combinations and asked to judge the relative "loudness" and "acoustical intimacy" of each event by marking a bipolar scale with increments of "1" to "10" indicated. In judging Loudness the semantic scale ran from "quiet" to "loud." For judging Intimacy the scale ran from "remote, distant" to "involved, close." No remarks were made to test subjects indicating an interest in the visual aspects of these acoustical factors and responses.

The results in judging relative Loudness are similar to Barron's findings given in Section 3. Moving from Posit. A to Posit. B where the level at B is lower, the sum of all judgments was that the subjective Loudness was the same at Position B. Multiple regression analysis of the data yields the following relationship:

$$\text{Loudness} = k' \,(G_{mid} + 0.162\, r) \qquad (2)$$

where r is the source-receiver distance, k' is a scaling constant and the Loudness units are arbitrary. As with Barron's results, the coefficient of r is found to be positive.

With the drop-off rate in level between the two seats being -0.146 dB/m for these tests, the coefficient of r in Eq. 2 indicates that in this hall under the visual test conditions presented, the perception of Loudness is essentially constant with distance from the source. Previous work has been reported by Hyde[39] on the ability of listeners under controlled listening conditions to discriminate changes of loudness in the early sound field. He found that subjects could distinguish the difference in sound strength G at a just noticeable difference (JND) of 1.0 dB. In the experiment at hand (see Fig. 3), G_{mid} decreases by 1.8 dB between Posits. A & B, yet the average judgment of listeners is that the Loudness remains constant. This finding further reinforces the argument given in Section 3 that visual stimuli play a role in the perception of Loudness in performing spaces.

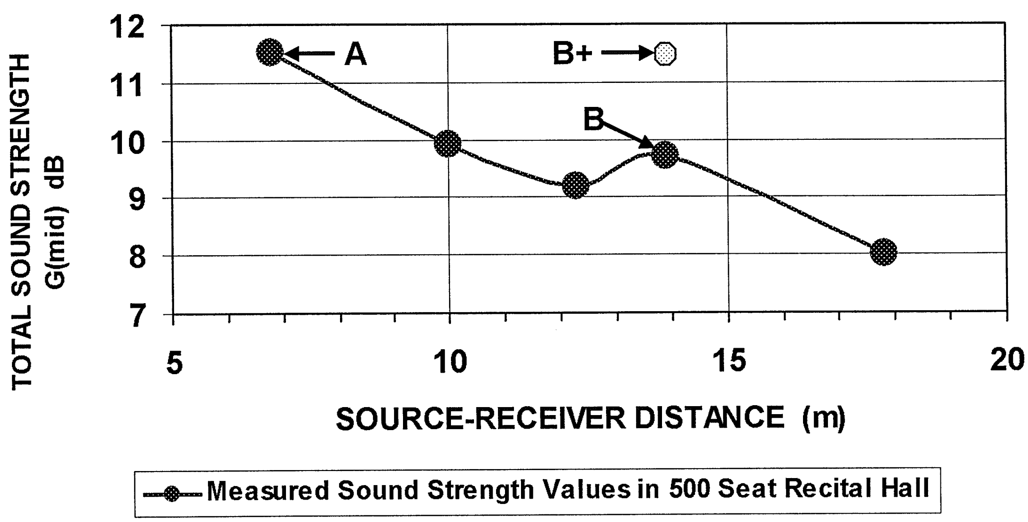

Figure 3 – Relative listening test sound levels. Levels at Position B are 1.8 dB lower than at Position A. Event B+ is at the same sound level as Position A.

In the judgment of the relative change in Intimacy listeners used a broad range of values on the bipolar scale and in general had less success in understanding the concept and judging the putative differences in Intimacy between seats and at varying sound levels. Greater variation in response was found between music motifs when judging Intimacy, than when judging Loudness. A slight increase in relative Intimacy was found as a function of objective sound level, however, with a correlation coefficient of only r=0.26 at 95% confidence limits. Judgment of relative changes in Intimacy included data from "Event B+." As in Section 3 we again connect the effect of Loudness increase with visual distance to support the contention that the perception of Intimacy is related to visual input.

6 INTIMACY AND THE PERFORMER

Intimacy is also an important issue for performers as well with the attribute relating to "contact with the audience."[40] Sanders[41] reports a comprehensive survey of chamber music musicians and their response to smaller chamber music halls throughout the country of New Zealand. The main criteria of overall judgment for the performers were Intimacy and "communication between players." The results indicate the three most important factors relating to a positive overall impression for the musicians were "support," "balance," and "ease of ensemble." All of these subjective factors can be related to the early sound field in the vicinity of the performer since distance between performers is on average constant. Of particular interest in this study is the range of size within the group of top-rated halls with volumes from 2,800 m^3 to 13,000 m^3. This points to the importance of the "local acoustical environment" as determined by the architectural design of the performer area.

7 CONCLUSIONS

Through listening experience, most acousticians believe that Intimacy has a visual component. Evidence from room acoustic measurements, subjective surveys and controlled listening tests has indicated that visual stimuli indeed influence our perception of the auditory event in that all experience is multisensory. There is direct evidence that visual factors affect our perception of Loudness where the visual stimulus of distance from the source alters the impression relative to the sound field; that is, the sound level decreases with distance but the perception of Loudness does not. Intimacy and Loudness are found to be directly correlated and the existence of a strong visual influence on them is compelling.

Sound field components in small spaces essentially define Intimacy and the issue for achieving Intimacy in large halls becomes one of reproducing as many of the components as possible. Since the direct sound level and source-receiver distance are immutable design factors, Intimacy is achieved by providing significant sound levels G_{tot} as comprised of rich early reflections and through maintaining as small a room constant as possible. In summary, concerts and operas are multisensory events with visual input having a clear influence on what we "hear" and experience.

8 REFERENCES

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