Journal of New Music Research, Vol. 26 (1997), pp. 70–95 0928-8215/96/2601-070$12.00

COMPOSER'S FORUM

Live Electroacoustic Music: Old Problems, New Solutions

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ABSTRACT

This paper presents some observations on certain fundamental issues associated with the presentation of music which combines performers and electronically generated and processed signals delivered by loudspeakers. I contend that several factors have limited the growth of the genre and will attempt to illustrate their origins and consequences. These comments lead to some general recommendations to correct the situation and to some observations from my own experiences as a composer and performer. Finally, I examine a few new technologies which may soon impact the genre.

INTRODUCTION

The maturing of MIDI (Musical Instrument Digital Interface) and low cost digital audio synthesis and processing software and hardware has led to a rapidly expanding repertoire of works for one or more performers plus electroacoustic resources. This repertoire poses a new role for chamber music performers in that the familiar temporal and structural control mechanisms (measures, clocks, conductors, auditory cues) have been augmented by computer-mediated processes and that the normal acoustical experience has been altered by the addition of loudspeakers. By interacting with electronic devices, computers and sound reinforcement technologies, musical elements normally outside the control of the player can be spontaneously and interactively reshaped and adjusted. The player becomes conductor, system manager, console and lighting operator, and in some cases originator and manipulator of the musical materials of the work. In short, the performer has been offered a completely new role in the subtle triangle — composer, interpreter, audience — and I suspect that as the tools become less obtrusive and more streamlined many players will champion these exciting developments.

This paper follows a line of thought I have explored elsewhere (Pennycook 1993) and presents some new observations on certain fundamental issues associated with the presentation of music which combines performers and electronically generated and processed signals delivered by loudspeakers. I contend that these problems have limited the growth of the medium and will attempt to illustrate why.

I will also present some recommendations for composers and performers toward improving the accessibility of live electroacoustic music and speculate on some new technologies which are emerging.

Live electroacoustic music has at least two quite distinct origins: music from the Western art traditions such as Cage's *HPSCHD*, one of the first multimedia "happening" pieces, and Karlheinz Stockhausen's *Microphonie*, which grew out of experimentation with live radiophonic equipment and procedures, and works from the popular music traditions. The electronic music of the European studios must be considered in balance with the much earlier use of amplified voice, electric guitar and bass employed by the blues and jazz bands in 1930s. It can be argued that this type of straight amplification does not actually qualify as electroacoustic music in that the microphones, pick-ups and amplifiers are engaged merely to provide sufficient projection in large halls. However, the current state of composed electroacoustic music owes much to the aggressive use of amplification and electronic tone modification by jazz and country guitarists such as Les Paul, Chet Atkins and Charlie Byrd, and by many blues artists who intentionally "pushed" the equipment striving for personalized timbral effects. Most of the music we hear around us today descends from this marriage of popular styles and audio electronics. Furthermore, most of the music we hear around us today is delivered through loudspeakers or headphones (live concerts having become ritualized into overpriced spectacles). It seems unlikely that anyone could emerge from the pervasive, inescapable din of music delivered entirely from loudspeakers with the same acoustic perspective of composers, performers and audiences a generation or two ago. Yet the acceptance of electroacoustic music, especially works which include one or more performers, has been limited. In general, the genre has failed to migrate into the regular concert world which most classically trained performers inhabit.

GENERAL ISSUES

The tutorial tradition: teaching teachers

Solo and small ensemble works from the live electroacoustic repertoire are generally not well known to instrumental and vocal performance instructors. A small fraction of music teachers may profess to being "contemporary music specialists". What this usually means is that they have a few well known works in their repertoire or they may have played some "new music" concerts at one time. Unfortunately, few actually specialize in contemporary (meaning post World War II) programs. Fewer still present electroacoustic programs and these instructors would benefit from greater familiarity in order to present contemporary and electroacoustic pieces in a positive manner with the enthusiasm and respect

afforded to the standard repertoire. Consequently, their students are unlikely to consider the genre as worthy of the energy and professional commitment required for successful concert careers. The student may never learn that such works exist and that many professional performers build their careers through specialization in modern performance practices. Perhaps more important is that private tutoring in music is a very personal and sensitive experience for both teacher and student alike. I am certain that all of us who studied voice or an instrument can recall at least one teacher who openly criticized contemporary (meaning after Debussy) repertoire. Such attitudes often have a profound impact on young performers and are very difficult to dispel. Of course these tutors may truly believe that only through devotion to the standard repertoire can a young performer reinterpret the great traditions of Western musical culture. In time, the students believe that it is their solemn duty to continue this tradition and, in so doing, an interminable cycle of teacher-learner-teacher is sustained. This cycle is reinforced and encouraged in the curricula of most music institutions. Now, at the end of the twentieth century, courses in contemporary music remain as obligatory diversions to the real work — learning the standard repertoire and performing it in public. It is no wonder that the contemporary music heroes are not composers, especially living composers. Rather, they are specialists of music written in previous centuries who have succeeded in the concert tour circuits. It is nearly unthinkable that an electroacoustic work would be programmed on a major concert series or tour.

The paucity of music of our times in most music institutions is a problem of great complexity which I cannot fully explore in this brief paper. It should be clear, however, that whatever forces have succeeded in establishing a near religious devotion to the canons of Western music at the expense of contemporary musical forms are joined by more practical barriers to the introduction of electroacoustic music into mainstream music teaching. We can begin to address these issues by exposing music students to new repertoire and developing an expectation that recently composed music should appear on public recitals and ensemble concerts. Instrumental teachers, historians and theorists should devote at least a portion of their pedagogical curriculum to current repertoire including electroacoustic works. Some music schools now offer both practical and historical courses in electroacoustic genres (and in a few cases entire degree programs) and it is hoped that these efforts will awaken at least some of the students to the important innovations the pioneers and current practitioners of electroacoustic composition and performance bring to contemporary music of all kinds. But the most potent force in a young musician's life is their instrument teacher; the role of the master is indispensable in setting the learning stage and in ensuring that not only techniques and expressive manners are passed on but also artistic values and a genuine interest in the music of our time. Perhaps some of the recommendations below will help the teachers and learners to shift their focus to this genre.

An accessible tradition: performance materials

Traditional repertoire materials — scores and parts — are readily obtained from stores and libraries (and, I might add, countless illegal photocopies). Recorded versions abound. Most published works have been carefully edited and annotated. The notation is straightforward and the musical demands fall within the normal scope of instrumental and vocal technique. In short, no special demands are placed on the performer to find and access these works.

With few exceptions, this is not the case for contemporary music. Contemporary scores and parts often abound with specialized notation and symbols, unconventional performance practices, and isolated passages which are far more technically difficult than other parts of the same work. Lacking the comfort of historical tradition and the availability of recordings and faced with extreme notational and technical demands, performers who venture into this domain must rely on the materials provided by the composer or publisher or on direct (in-person) assistance by the composer. When engaged in the acquisition of contemporary repertoire, players must expect to divert unreasonable amounts of time from the other pieces in their repertoire. This seems to pose a major obstacle to the growth of the genre, and any impediment to learning, polishing and presenting an unfamiliar piece significantly diminishes the probability of performance.

The problem is more acute when dealing with electroacoustic music as no standardized symbolic representations exist. In general, composers do not provide adequate information in the performance score and the accompanying electroacoustic resources for players to feel sufficiently confident to learn and present the works on their own. I have witnessed nearly impossible rehearsal situations where the players and conductors have been completely baffled by the relationship between the instrumental/vocal parts and the electroacoustic parts. The problem rests primarily with timings and their representation as symbols on paper. Long continuous passages which must be matched against complex instrumental parts may necessitate rewinding the tape to a clearly identifiable point (possibly the beginning of the piece!) every time the players get lost. Similarly, passages with extremely complex metering not reflected in the electroacoustic part by recognizable pulses or acoustical landmarks of some kind also pose daunting rehearsal problems. Whatever technique is employed such as stop watches, click tracks, electronic metronomes, time-code, etc., it is essential that the cues be accurate and readily understood. A score which has been prepared primarily as an illustrated guide to a fully realized performance or recording may not be sufficiently instructive for efficient and productive rehearsing.

The electroacoustic component of the work may also pose unnecessary problems. It is simply counterproductive to take the position that a difficult work

should be "figured out" by the performer or conductor who must realize the work with whatever materials are made available. Effort and care by the composer to provide performance materials which are accurate and thorough and which can serve a kind of tutorial function will contribute measurably to the adoption of more electroacoustic works into the repertoire stream. Once a performer has invested the time and mastered a new piece, it is highly likely that the work will receive multiple performances. Hence, it is incumbent upon the composer to prepare high quality performance materials which simplify and streamline the learning process. Some composers actually demand elaborate electroacoustic installations which, without the presence of skilled technicians, are utterly unmanageable. Furthermore, the synthesis and sound-processing gear needed to present live electroacoustic works is not normally available in public recital halls. Even if it were, most classically trained players have little or no training in the operation of such equipment. Here we have a circular problem — if the players do not place such works on their programs why should recital halls invest in the audio equipment, and, if the halls do not have the equipment, why would a player learn works which require that he/she purchase and portage their own gear?

The concert tradition: the listening experience

Today's concert audience brings to the concert hall different listening sensibilities — those from the world around them delivered exclusively from loudspeakers and those of the acoustic instruments and classical music. But concert audiences presented with electroacoustic repertoire are often troubled by the inequality of the acoustic and amplified sounds. In a concert of traditional material, piano and flute for example, the listener develops a familiarity with the sonic ambiance of the instruments and the hall. This can be severely disrupted by the intrusion of loudspeakers. Listeners are expected to change their auditory perspective from acoustic-only signals emanating from a three dimensional source (all the players on stage, the stage itself, the hall) to an artificial stereophonic (or multichannel) image emanating from highly directional loudspeakers. In much the same way that an unamplified piece at a rock concert (for those close enough to hear it!) seems out of place — a kind of instantaneous *sonic dimming* of the total experience — the sudden presence of loudspeaker signals in the concert hall distracts and alienates many listeners. While I am not prepared to offer a formal analysis of the problem, the likely cause for this disparity lies in the human perceptual mechanism as described in Bregman 1990. Acoustical and loudspeaker signals presented in the same listening space often result in disjoint musical "streams" and most often are not heard as a fused, single entity unless some very precisely controlled acoustical conditions are met. Certainly the judicious use of multiple, high quality speakers can do much to minimize (and in rare cases eliminate) the gap. But the dichotomy

of acoustic and loudspeaker sound in halls in which a grand piano or solo trumpet can seem too loud poses unusual demands on the listener when presented in the same context. I will return shortly to the problem of halls and sound reinforcement.

In summary, these three perspectives — composer, performer and listener — must be correctly balanced for the genre to flourish. Presenters of a musical form which has its origins in both concert music — an acoustic listening experience — and jazz/rock — a loudspeaker listening experience — must strive to engage audiences in aesthetically compelling and musically satisfying ways. While the technological and musical demands pose difficult problems for teachers, performers, hall operators and listeners, we must remember that the majority of electroacoustic works form a subgenre of chamber music and that historically, chamber music pieces have been perpetuated primarily because players select them for concerts. Issues of compositional quality aside for the moment, I would hope that at least some of the new electroacoustic pieces will achieve the same level of acceptance and frequency of performance as the standard repertoire. However, the burden on the composer, performer and hall operator to address all of these issues significantly reduces the likelihood of presentations.

LIVE ELECTROACOUSTIC MUSIC: COMPOSITIONAL MODELS AND PRESENTATION STRATEGIES

Part of the joy of music is the apparent simplicity and spontaneity of live performance. The astonishing number of chamber works from the 18th and 19th centuries still performed today indicates that the balance among compositional language, performer acceptance and the audience's listening experience was and remains in good proportion. From dormitory common rooms, church auditoria and conservatory stages to the major recital halls throughout the world, the presentation of traditional repertoire thrives in a familiar and well understood artistic and social framework. Another equally well understood musical experience presented in every manner of venue — church basements, hopelessly echoic hockey arenas, clubs and the largest sports venues holding an audience of many thousands — are rock concerts. Here the combination of "music which sounds like the CDs I play at home", grand spectacle (often dressed up as "theme shows" like the Rolling Stones recent Voodoo Lounge tour), and audience expectation are in good balance.

These two familiar modes of musical experience — the (acoustic) chamber music recital and the (electroacoustic) pop/rock show seem to be mutually exclusive with respect to the sonic experience presented to the listener. Electric guitar in a chamber recital rarely works. Similarly, most efforts to fuse chamber ensembles or even large orchestras with rock or jazz groups have failed artistically (though not necessarily commercially). That is, with very few exceptions, hybrid

forms are considered by composers, performers and audiences to be merely musical curiosities. Certainly at issue are problems of compositional language and modes of performance. The sounds of the instruments and how they are played present an expectation which often is not fulfilled when electronic or improvised music is inserted into fully composed instrumental settings. When we see a drum set or high powered guitar amp on stage we more or less expect that they will be played with the same level of energy and freedom as in their usual settings. Similarly, the compositional intricacies and subtle timbral nuances of chamber music forces cannot simply be enlarged through amplification in the hope of achieving the same kind of drive and sonic power we associate with the rock setting. But, are there circumstances or conditions which permit these two musical worlds to be joined to produce new, effective works suitable for both concert stages? What models exist which may help point the way?

Film music, like rock, is delivered through loudspeakers and from the time of the first "talkies" in the late 1920s, composers in the commercial media industry adopted the position that any musical or acoustical source which would yield practical and effective audio and music tracks for the project at hand was fair game. Hence movie, television, and commercial sound tracks are often based on a kind of musical *plundering*, a practice creatively pioneered and illuminated by Canadian composer John Oswald (1986). In the movie industry, not only are musical materials and idioms freely borrowed, but the *sonic* qualities — the sounds of things as cultural signifiers — are also borrowed to assist the film sound designer or editor to construct potent acoustical images which cement the visual images in the audience's mind through carefully chosen external musical and sonic references. The overriding principal here is that the primary function of the movie sound track is to enhance the visual materials through the use of highly referential sounds and musical selections. However well this works for film and video, this principal cannot be applied directly to concert music. One need only turn the television off during the playback of most commercial movies and listen to the sound to realize immediately that even the most basic compositional principals of formal design are sacrificed to the moment-by-moment demands of the unfolding action. While the musical experience in the movie theater (or home) comes to us through loudspeakers and not, as in the early days of cinema, from live performers, the aesthetic forces which dominate the movie music process do not provide good models for electroacoustic music in the concert hall. Moreover, film music is constructed entirely from prerecorded clips which are assembled into a continuous stream inextricably locked to the temporal progress of the visual materials.

The composition of works for tape alone emerged from the radiophonic studios in France and Germany in the early 1950s and engendered a powerful and unique musical genre. For the listener, electroacoustic works of this type are more closely aligned with the movie music experience than the concert hall experience. Through

the fabrication and manipulation of acoustic (concrète) and electronic (synthetic) sound sources, composers realize a series of auditory scenes which are intended to carry the listener through an abstract auditory drama. Canadian composer Robert Normandeau, among others, approaches this *cinéma des orielles* as an essentially multichannel, multispeaker genre (Normandeau 1994). During a "performance", the composer or interpreter can control the spatial distribution of the audio — a process known as *diffusion* — with the intent of enhancing the acoustic imagery of the prerecorded materials. This method of presentation can be very powerful and musically satisfying. However, it demands an appropriate listening space, especially when eight or even sixteen audio channels and loudspeakers are engaged. The most elaborate approach to multispeaker presentation of loudspeaker music is the system developed at Birmingham University, called The Beast. Like the massive "orchestral" organs of the 19th century, this system is the king of loudspeaker orchestras designed to reproduce and spatialize electroacoustic sounds in minute detail and breathtaking sonic accuracy. A small but growing body of works exists specifically for multichannel systems like The Beast, but obviously such elaborate solutions represent levels of financial and technical investment far beyond most composers and most venues. The Beast and other complex speaker arrays, though ideally suited to the tape music genre, cannot readily serve the performer of live electroacoustic unless, by chance, she/he has been engaged to present a concert in a fully equipped performance space.

Neither the film medium nor the specialized systems for the realization of tape music idiom offer practical models for the presentation of live electroacoustic performance. First, the interpreter of tape music (if anyone at all) is most often the composer, not a performer in any usual sense of the term (We can ignore film in this regard as the projectionist normally does not contribute actively to the visual or auditory presentation). Second, the equipment is not portable and in most cases far too expensive for most players. Third, audience expectation is closely linked to the sonic qualities of loudspeakers, and as I have established above, these expectations become confused when presented with more traditional acoustic forms. Fourth, the most suitable venues — large theaters, planetaria, galleries, outdoor installations — are acoustically inappropriate for most instrumental and vocal presentation. This final point requires closer examination.

Loudspeakers and halls

The successful design and installation of sound reinforcement systems for the concert halls, especially older halls designed for acoustic instruments and voice, poses many challenges. Countless manufacturers, consulting firms, acoustical architects, rental firms and skilled technicians are engaged in attempts to provide high quality sound systems which integrate well with the sonic properties,

architecture and visual elements of the space. Halls with sufficient financial resources can purchase fine systems which complement the unamplified signals perfectly. In some cases, such as highly echoic cathedrals, the addition of multiple loudspeaker systems which have been time-aligned to minimize echo and reverberation problems can actually enhance the listener's experience in the hall. Venues which present rock or jazz on a regular basis now have high quality, multichannel systems for sound reinforcement. In many cases these have been professionally designed, installed and precisely aligned for the conditions of the space. However, the recital halls and small auditoria where most chamber music is performed rarely have adequate (or any) audio equipment. General purpose auditoria with in-house support for public address and film/video presentations usually are not set up for the high fidelity and wide dynamic range requirements of electroacoustic music. In all cases, the electroacoustic music performer is obliged to accommodate to conditions which exacerbate all the other forces working against widespread dissemination of electroacoustic music.

American composer, Dexter Morrill (1981), has explored the interplay between soloist and the often visually and aurally obtrusive speaker cabinet. In one movement of his *Six Dark Questions* for soprano and computer generated tape, the soloist engages in a dialogue with a single speaker box placed stage-center facing the soloist. Of course this solution has limited artistic application but for during this piece the audience is drawn into experiencing the speaker (and hence the electroacoustic signals) as an animate and dramatically essential element of work. What Morrill and others have attempted to correct is the fundamental conflict between an acoustically complete stereophonic image delivered from loudspeakers versus the instrumental and vocal signals which are subtly amplified and "processed" by the hall itself. While the hall usually detracts from and interferes with the electroacoustic stereo image, painstakingly assembled and mixed in the studio, in most cases the instrumental and vocal signals are enhanced by the spatial contributions of the performance space. An aural dichotomy between acoustic and electroacoustic materials is inescapable unless these forces are reconciled.

There are two solutions to this problem. One approach is to "eliminate" the hall. That is, amplify all the signals by miking everything on-stage and delivering a complete stereo or multichannel mix through two or more loudspeakers. Unfortunately, this only works in cases where the acoustic signals from stage are sufficiently contained. In most good halls in which I have performed, the reality is that the space has been designed to amplify and distribute on-stage acoustic sounds throughout the room without the assistance of speakers. The sound pressure levels from stage are sufficiently strong without electronic reinforcement. Add to this the high levels required to completely balance the stereo image from the speakers and almost certainly the overall sound pressure levels will exceed the tolerance of most concert-going audiences. In some halls, especially those designed

specifically for amplified sounds, a simple two-channel sound system will be adequate for many electroacoustic performances. However, these are not the venues normally available to performers of contemporary music.

An alternative (or companion) solution to miking and mixing in an attempt to neutralize the hall is to integrate the loudspeakers on-stage with the players and to set amplification levels roughly equal to the acoustic forces. Consider the simple case of a chamber work for mixed instrumentation plus one or more synthesizers. Sending the synthesizer signals to a pair of speakers many meters away from the ensemble will result in the kind of acoustical fragmentation (auditory streaming) I have been describing. There may be rare cases where the electronic sounds of the synthesizer are intended to be sonically remote from the group, but in general the best solution is to place a small loudspeaker close to the synthesizer player and project sound from the stage blended acoustically with the other unamplified sources. This solution often solves the problem of monitoring in that the player, the instrument, and the sound sources are all in one place.

This approach can be extended to most works involving loudspeaker and acoustic sources. Rather than *eliminating* the acoustical properties of the hall through large-scale sound-reinforcement methods, the electroacoustic material can be positioned on-stage by placing the speakers among the players and by restraining the sound pressure levels to match the acoustical dynamic range of the unamplified sources. It may require many very high quality speakers, each responsible for specific musical materials, to match the presence and subtle dynamic shifts of the acoustic sources. The drawback, of course, is that the amount of machinery needed is rarely available and almost certainly is not within the means of most chamber groups. The imbalance of available resources, materials, and venue generates strong resistance to the regular presentation of such works.

Regardless of the hall or the amplification technique, composers today cannot assume that performers of their live electroacoustic works will have access to loudspeaker systems which are capable of providing sound pressure levels and radiation properties complementary to the combined forces of acoustic and electronic sounds. However, for the music to flourish, some practical guidelines which composers and performers can refer to may prove useful.

TOWARD A PRACTICAL LIVE ELECTROACOUSTIC PERFORMANCE SYSTEM

I have established some key issues affecting composers, performers, hall operators and audiences which at present severely limit performance opportunities for live electroacoustic music: most live electroacoustic music falls under the broader category of chamber music; Performers determine the adoption and dissemination

of the repertoire; Composers cannot be present at each and every concert and must provide instructive and thorough performance materials; Suitable audio systems must be available; Electronic and acoustic forces must complement each other from a sonic perspective. These observations suggest that composers must be sensitive to the historical traditions and current realities of chamber music performance and design their works around systems which are appropriate for these circumstances. The obvious counter argument is that composers are free to demand any resources they so choose and this is clearly irrefutable. However, many composers in film, music theater, dance, church music, drama, etc., are quite comfortable with real world limits. Most commissioners of new works also impose practical limits such as instrumentation and duration. I contend that such limits should also apply to live electroacoustic music systems.

Several technologies may be useful to address these problems. They range from very inexpensive and best for instrument and prerecorded music to moderately expensive and suitable for all forms of live electroacoustic music.

Audio CD

I could end the discussion here by simply stating that all works should be composed exclusively for unamplified instruments and compact disc. No computers, no MIDI systems, no special custom devices — just plug the CD player into a powerful sound system and play. CDs even address the rehearsal problem in that numerous indices and subindices can be encoded with the audio tracks. The index counters display precise and sufficiently detailed information for most cueing circumstances. Remote control units further simplify device control during rehearsals and performances. This argument can be extended to DAT but the availability of DAT players is low compared to CD players and, unlike random access CDs, DATs are sequential and must be rewound or forwarded to locate specific rehearsal points. Most performers own their own CD unit and many own small portables like the SONY DiskMan. Hence, for tape plus instrument works this is indeed a solution with nearly universal applicability.

CD-Extra

The audio CD solution does not adequately address the problem of training. I suggest that with only slightly more effort, composers could prepare CD-Extra (or CD-Plus) units. These are CDs which may be played in any standard audio CD player but also carry an "extra" track (usually Track-1) which is a file system. The file system can be read on any CD-ROM unit in a Macintosh or Multimedia PC (M-PC). The contents of the file system can contain a set of text files, scores, images of performance setups, video clips of prior performances, etc., or it can

contain a database such as a HyperCard stack or an executable program generated by MAX or Director or any authoring tool. With only slightly more development effort, a graphic interface (instructions, buttons, help, etc.) which provides on-screen triggers to the appropriate audio section could be added to guide the player. There are many simple, low cost authoring tools available for Macintosh and Win95 which reduce the preparation of hypermedia packages to "click-and-drag". Presumably, if one can use a CD-ROM, one can make one with these tools. The attraction of CD-Extra is that once the piece is learned, the performance setup requires nothing more than a conventional audio CD player and an audio system.

CD-ROM

A more complete solution is offered by CD-ROM which offers a very important advantage over CD-Extra in that the integration of media types is fully integrated. The clear disadvantage compared to CD audio or CD-Extra is that CD-ROMs require a computer equiped with a CD-ROM drive and an audio system. However, the current generation of personal computers are usually packaged with multimedia subsystems and these can all play audio from CD-ROM. The combination of presentation software and individual media tracks is referred to as a multisession CD-ROM. That is, the folders and files forming the presentation software are recorded on the disk separately from the audio or video media tracks. This poses no special hurdles for our application. A CD-ROM containing the score and parts, program notes and biographies, installation information, scanned images of wiring diagrams or stage setups, training guides, video clips of rehearsals or performances, plus all of the requisite audio tracks can be assembled into a single, well organized presentation. The performer will benefit from the ease of use, the training materials, and from the fact that all the materials — score, parts, software, audio, video, etc., will be packaged together.

The World Wide Web

An alternative to CD-ROM is to utilize the World Wide Web as a means of distribution. All WWW browsers such as Netscape and Mosaic support hypermedia information which can include: text, images, audio, video and MIDI. Executable software, such as a MAX application, can be shipped to the user using the standard file transfer protocols (ftp) mechanisms of the Internet. The Web offers some very important advantages over CD-ROM in that the files and media can be maintained and updated by the composer at any time avoiding the problem of issuing revisions and/or updates. Furthermore many new tools to present musical materials are being developed by Pennycook (1996) and others. However, there are two major disadvantages to a WWW based solution: the audio tracks would end up on the end-

users hard disk and could only be played with an appropriate control software such as MAX, and there is no simple way at this time to limit, control or charge for these materials once they reside on a publicly accessible WWW server. For some, this may be very troubling. At this time, I suspect that most composers would prefer the artistic control CD-ROM offers. However, the WWW boasts many millions of users, many of whom have developed strong interest in new musical forms. Equally important, distribution costs are negligible compared to pressing, printing and mailing CDs.

MIDI

While some electroacoustic music composers shun MIDI, there is a growing body of works for algorithmic composition, MIDI-controlled synthesis and signal processing and interactive performance. Compared to digital audio on compact disks, these works are extremely difficult to replicate. Too often these pieces specify one or more MIDI devices which may or may not be available to the performer. Many older MIDI devices are now defunct and cannot even be rented. Most studios dispose of outdated units as soon as they fall out of fashion. It is unlikely that works for defunct instruments and platforms can be revived without a great deal of effort. However, a complete, generalized approach to the use of MIDI for live electroacoustics is essential especially considering its omnipresence in the music industry.

Some important developments in personal computer capabilities suggest some interesting possibilities for MIDI. First, MIDI interfaces are readily available on all machines — on M-PCs MIDI interfaces are included with all sound cards and on Macintosh simple MIDI interfaces such as those from Apple or Opcode are very inexpensive and, more important, these interfaces work equally well on portables and desktop models. Second, there are several products which offer MIDI-controlled sound sample players which, in the case of M-PCs reside on the sound cards and in the case of Macintosh, reside in memory. Some of these products permit the developer to import their own sample libraries from a variety of commercial and public domain sample editors. With the reduction in memory prices, very large, custom-made libraries which can be prepared, loaded and controlled during performance without the need for external MIDI hardware become practical. The fidelity of the audio signals from most of these products can be configured up to compact disk quality (44.1 k samples per second, 16-bits, stereo). Thus, high quality MIDI samples can be performed directly from a laptop machine and the audio sent directly to loudspeakers.

Another clear advantage of MIDI is that is can be used for many purposes other than sound synthesis and sample playback. These might include: user interface systems which collect data from the players in the form of MIDI controllers or

notes for triggering or real time interactive composition procedures, real time control of outboard signal processing devices and effects units and MIDI Machine Control (MMC) to synchronize performances with external hardware such as video tapes or lighting systems. While some of these suggest elaborate external hardware, interactive control and algorithmic composition can be performed entirely within the computer software. Some of the most recent in-memory MIDI systems, like Cybersound-VS (1995), also offer limited effects and reverberation capabilities. Many of the M-PC MIDI sound cards offer reverberation and more as built-in hardware capabilities.

MAX

MAX (Zicarelli & Puckette 1990) is the most widely used language for live electroacoustic music and no discussion about live electroacoustic music or MIDI would be complete without commenting on this highly important contribution to the field. MAX is extremely powerful and general, yet it is relatively easy to use. Furthermore, there are innumerable MAX programs available over the WWW and from listservers which can be used and modified as needed. However, it is unfortunate that MAX, the software used by most composers for interactive, real time performance and composition, is not available for Windows platforms as that limits the field of low cost computers significantly. On Apple Power PCs, MAX supports many of the features described above including all MIDI functions, user interfaces, algorithmic composition, CD audio and CD-ROM control and playback of multiple compact disk quality audio files from hard disk. In addition to electroacoustic composition, MAX can be used effectively for everything including building and conducting music perception experiments (Costa-Giomi and Pennycook 1994), performer-controlled accompaniments for rehearsing standard repertoire and sophisticated user control systems for high end analysis-synthesis devices. The configurations described herein are readily applicable to all of these cases.

These conditions suggest that a minimum capability should include digital audio, MIDI, MAX and fast response times for interactive procedures.

A minimum system specification

A portable, generalized live electroacoustic system which can provide instructive materials as well as the presentation capabilities must satisfy several conditions. First, the hardware and operating system must:

1. be light-weight and reliable
2. support compact disk quality digital audio playback (two or more channels)
3. provide access to and control of CD-ROM
4. include MIDI input and output (and possibly hardware sample players)

5. include sufficient memory to support in-memory sample playback
6. include sufficient processor bandwidth to support real time audio processing
7. support process multitasking
8. support access to an Internet Service Provider and 28.8 Mbps modem

Second, the system must provide reliable and easy-to-use software. As a minimum this would suggest:

1. Opcode MAX
2. commercial sequencer
3. presentation system or player (like HyperCard)
4. postscript viewer and printer downloader (for scores and parts)
5. Internet connection package

Third, a small number of commonly available peripherals will be required for most pieces. These might include:

1. MIDI input/output device for nonkeyboardists (such as Anatek Pocket Pedal, etc.)
2. foot switch, volume pedal

Fourth, a minimum quality sound system must be available for rehearsing and performance in small venues. We can assume that large venues will provide at least a stereo sound system suitable for the space.

1. MIDI controlled multieffects unit such as the DigiTech TSR-24 or Ensoniq DMP-4
2. stereo audio system (possibly a pair of self-powered speakers which range from superb such as those from Meyer Sound Laboratories to rehearsal grade such as BOSE Video Roommates)

Unfortunately, no computer on the market today matches exactly all of these requirements. However, I am prepared to propose that the following may be very close and that with some announced improvements to certain pieces of software may indeed satisfy all the requirements.

Proposed electroacoustic performance system

Table 1 suggests a minimum system which can support many compositional styles and techniques. This system is intended as the target performance system and not necessarily the system a composer might use to develop a new work. This simple, highly portable rig can generate a wide variety of electroacoustic materials. It would cost about as much as a good bassoon which most institutions and many players could afford. Of course, the system would be useful for all other aspects of the musicians career including correspondence, accounting, multimedia viewing, etc.

While there are many aspects of a similarly powered Win95 portable that are desirable, especially process multitasking and well developed multimedia support

Table 1. A minimum performance system.

Component	Function	Rationale
Apple PPC Powerbook 32 Mbytes DRAM color screen	Portable computer	Lightweight, powerful, modest cost multitasking announced for early 1997 program, sample and audio memory best for user interface, video, etc.
External 4X CD-ROM Drive	CD audio, CD-ROM	Fast, audio output jacks isolated from the computer system (not like internal CD-ROM units)
Modem (28.8 kbps)	Data transfer	Internet, e-mail, WWW, etc.
Opcode MIDI Translator	MIDI interface	Cheap, reliable, data LEDs useful
Anatek Pocket Pedal, Pedals	Switch and volume	Simple interface for triggers and controllers
DigiTech TSR-24 (or equivalent)	Reverb, effects	Inexpensive, 4 channels (multieffects) uses standard programs, no editing
Portable DAT machine	DAT pieces	Many works in DAT format only
Opcode MAX Software	Control software	Widely available, very flexible, runs on Apple OS and likely to survive several generations, supports multifile digital audio playback on PPC hardware
Apple Quick Time Music	In-memory sampler	Announced new version supports 16-bit, 44.1, stereo samples, user-libraries, full integration with Quicktime and new Sound Manager
Other software	As needed	Sequencer, notation package, web browsers, word processing, accounting, etc.
Audio Technica microphone	Amplification	Most works require sound reinforcement
Mackie 6 in, 2 out mixer	Mic, effects send	Small, lightweight mixer for all audio streams
Two self-powered loudspeakers	Audio support	Guarantees the player a reliable audio playback source; multiple inputs

at this time no PC version of MAX exists. Also, sound cards differ greatly and cannot be considered predictable, general devices.

In this section, I have presented a minimum system specification and suggested a possible hardware configuration which satisfies most of the requirements. This

system would go a long way toward providing composers and performers a reliable live performance setup. However, the impact of such as system on composers, performers and teachers must be considered from several perspectives.

IMPACT OF THE PROPOSED SYSTEM ON COMPOSERS, PERFORMERS AND TEACHERS

Composers and performers may completely reject the proposals I have enumerated above on the grounds that they are too limiting artistically and represents far too much effort. I have no real arguments for either of these other than restating that the conditions that prevail today severely restrain the growth and dissemination of this music. The proposed system would significantly simplify the demands placed on performers. If a body of works emerges for a variety of instruments or voice and interactive electroacoustics and if the performance materials are thorough and instructive one of the major impediments to the likelihood of repeat performances would be minimized. As a performer of new music and as a concert producer I would welcome such a move toward standardization. As a teacher and instrumental coach, I would be more likely to assign works from the genre knowing that the effort required to master a work could lead to many presentations and eventually form an integral part of the players' repertoire. More important, the instructional materials proposed herein would eliminate much of the difficulty of teaching these pieces. The student would work directly with the piece in its entirety (not just the soloist's part and a cassette recording) thus allowing an integration of the interactive and live electroacoustic components to become part of the training process from the onset. Perhaps music institutions could own one or two systems to be signed out like the video playback trolley or the rarely used E-flat contrabass clarinet. Also, the availability of the system(s) must be decoupled from the electronic music studios or computer labs and put directly in the hands of the performance teachers and students. In short, using the live performance system must become as commonplace as the pianos in the practice rooms or the word processors in the library.

However, there are some other more practical considerations which composers must understand fully before embarking on a new work within the system specifications. These considerations are functions of the processing speeds, audio retrieval speeds, and the event-response times of a typical multimedia computer system. Other important limitations emerge from the inconsistencies of MIDI hardware and software.

Event response times

The music and audio subsystem of M-PCs and Power PC Macintoshes can be divided into three main categories: digital audio, MIDI controlled synthesis cards (or external units) and internal sound resources. The most important consideration in designing a work which utilizes these three components is the "system latency", meaning the elapsed time from the instant of requesting a response (such as a MIDI trigger) until the desired action occurs (such as the start of a new audio track). Table 2, entitled Sound Resources, outlines the type of resource, the smallest control element, and the most important resultant limitations.

Table 2 also illustrates that some important compositional decisions must be made very early in the genesis of the work. These may be summarized as follows:

Table 2. Sound resources.

Resource	Control level	Limitations
Digital Audio (CD-ROM)	Track, block	Random seek in excess of 100ms average fixed sample rates (8bit, 11k, mono; 16bit, 44.1k stereo) Control response time in excess of 20ms Very large storage capacity Limited processing capability due to high sample rates
Digital Audio (hard disk)	Track, sector, frame, sample	Track seek times fast (better than 15 ms) 2–4 fixed sample rates Control response times less than 1 ms Storage in excess of 60 min continuous play Processing dependent on cpu capacity
Digital Audio (memory)	Segment, sample	Instantaneous response All hardware supported sample rates (can be controlled explicitly by the software) Very limited and unpredictable storage capacity Processing dependent on cpu capacity
MIDI Synthesis (external)	MIDI, mouse, kbd	Unlimited resources possible but entirely unpredictable
MIDI Control (memory)	MIDI, mouse, kbd	Instantaneous response times Fully configurable (samples may be loaded from CD-ROM source) Very limited and unpredictable storage capacity
MIDI Synthesis (internal card)	MIDI, mouse, kbd	Instantaneous response times Voice capacity limited by hardware Sound quality limited by hardware Numerous control parameters

1. simultaneities can best be achieved with in-memory audio (less than 1 ms latency) and with MIDI (1–30 ms latency)
2. hard disk response times are good (less than 20 ms latency) but normally only one stereo file can be accessed at once (without software that can mix in real time)
3. CD-ROM access times are very slow and must be used only in cases where entry times may be delayed without altering musical intentions

The composer must remain aware of the latency times to ensure that performer actions result in event response times slightly later than the system component can accommodate. For example, it is unwise to expect that one or more CD-ROM players will be able to seek to new (possibly far) locations on the disk and start playing sound in the same time frame as the initial attack of a percussion or piano instrument. However, the selection and playing of separate audio tracks from CD-ROM in the context of several bowed string tones may accommodate a more relaxed level of start-time precision.

MIDI inconsistencies

The limits of MIDI synthesis and sample playback are well known and need not be revisited here. However, the elimination of external equipment, no matter how plentiful they may seem today, is an essential step. Discontinuing external MIDI modules suggests that composers must either use the samples which are provided with commercial sound cards or in-memory sample players or they must learn how to acquire, modify and import their own sound libraries. Another limitation is that the audio signal quality of personal computers is totally dependent on the quality of digital to analog conversion hardware provided by the hardware. While D–A converters have improved significantly over the past two years, the manufacturers of equipment for noncritical applications such as multimedia sound are not likely to use the grade of converters, filters and connectors found in mid- to high-priced audio systems.

MIDI can be a very powerful tool for live performance, interactive composition and for general machine control. Sound synthesis using MIDI control can also be very effective in the hands of a clever sound designer. The in-memory systems may not yet provide the richness of the high end gear but, as processor speeds increase and memory systems get cheaper, it is very likely that full function, high quality MIDI tone modules and signal processing software will be available for both Macintosh and M-PC platforms.

SOME PERSONAL EXAMPLES: THE PRAESCIO SERIES

In my own works I have striven to minimize the need for new performance techniques and to focus on the problem of performance automation. The first five pieces in the PRAESCIO series of compositions (Pennycook 1991) utilize a robust and easy to understand software package called MIDI-LIVE which essentially gives complete control over the temporal delivery of the work by the soloist. This system has been used effectively by myself and by Dexter Morrill who has developed works which were shipped to a player for a concert tour without the need for the composer's presence. Although the MIDI-LIVE software proved completely reliable, I have since recoded all of these pieces in MAX.

PRAESCIO-VI for solo flute and interactive system was completed in 1993. In this piece, I have taken the control framework of the MIDI-LIVE software several steps closer to a fully automated system. All of the software was implemented in MAX using an external object developed at McGill, called *playSMF*, which encapsulates all of the key features of the MIDI-LIVE system. In PRAESCIO-VI, not only does the player interact with the machine to control temporal actions of MIDI data but also to control the delivery of stereo digital audio data stored on a hard disk. This added a new dimension to my compositional method in that the limitations of MIDI hardware synthesis were overcome by mixing digital audio passages with MIDI generated sounds. Most of the computer-controlled material was precomposed (MIDI and digital audio files) while some of the accompaniment results from algorithmic manipulation of incoming flute data (via a pitch-to-MIDI converter) during a performance.

An important aspect of PRAESCIO-VI has been the development of a new technology called the MIDI Time Clip (Pennycook & Johnstone 1992) which is a MIDI messaging device built by myself and Eric Johnstone. Via MIDI, the software controls a small display unit attached to a music stand. In this work, the player received numerical information (rehearsal numbers) to guide her through the many cues and events (moments of player/machine correspondence) as well as tempo cues delivered by a readily visible red lamp (about 2 cm in diameter). Within one rehearsal the flautist had fully integrated her part with the computer part by following this simple inexpensive electronic conductor. PRAESCIO-VI used too much equipment. I have had performances in several cities as far away as Mexico City and every performance had some minor problems due to equipment or software. The only performance for which I was unable to attend posed nearly insurmountable headaches for the flautist. I learned an important lesson with this piece.

PRAESCIO-VII (piano... and then some) for acoustic piano and interactive system was premiered by pianist/composer Alcides Lanza in 1994 and recently released on compact disk (Lanza 1996). It expanded upon the methodologies of the

flute piece in several important ways. First, digital audio forms a central component of the work. It is delivered from two external CD-ROMs controlled by MAX thus permitting four channels of prerecorded audio from two random access devices. Second, the MIDI Time Clip was engaged to provide precise feedback to the player in the form of event numbers (like rehearsal letters), count-ins (lamp flashes), measure count (in places where there are clear metric units) and elapsed time in seconds count (for sections of unmeasured digital audio accompaniment). Another new aspect is the sonic presentation. On stage, four stereo pairs of loudspeakers are arranged in an array clustered around the piano. The intention is to provide a larger radiating source than two speakers can deliver. The eight speakers are all near the piano, rather than many meters away in the stage corners or in a circle around the audience. They project sound from the stage up to the same maximum sound pressure levels as the concert grand piano at fortissimo. The piano, which itself is a very large sound radiator, is amplified only enough to enlarge the region of radiation on stage and to provide a seamless balance with the electroacoustics. Just as the trumpets in an orchestra come from a specific place on stage, the four MIDI generated channels and the four digital audio channels have unique positions around the piano. The effect is an enhancement of the spatial projection in the hall achieved with comfortable sound-pressure levels.

I am currently in the process of preparing a "road version" of the work for a South American tour by Alcides Lanza and singer/actress Meg Sheppard. Access to specialized equipment in most centers in South America is very limited and touring with large, heavy equipment is out of the question. Although the original version of PRAESCIO-VII uses a modest amount of equipment it is still far to clumsy to take on tour. The new, compact version will look much like the proposed performance system. A Powerbook 5300cs, external CD-ROM, small effects unit and one, light weight MIDI sample module. The performers will carry a small mixer, DAT and CD player and will rely on the venues to provide audio equipment. I am confident that this highly portable system will accommodate all of the electroacoustic forces specified in the original version.

My works in progress are all targeted at small, portable systems which, hopefully, performers will use to play these pieces in future concerts. I remain concerned that the MIDI capabilities of in-memory sample players will not match high-end devices from AKAI, or Roland and that for the immediate future some outboard MIDI gear may be necessary. However, I am totally confident that the rapid improvements in processor speed and music software designed for real time computing will soon completely eliminate need for external devices in my own works.

THE NEAR FUTURE

There are a few things about computers that nearly everyone knows are very likely to occur in the near future: they will get much smaller and much faster, silicon memory systems will get much larger and cheaper, fixed and removable media disk devices will soon rival silicon memory in speed and tape backup in capacity and will be produced in very small and reliable packages, full multitasking, multithreaded operating systems will become the norm, communications among computers will get much faster and become fully wireless, and embedded microprocessors will appear in nearly every consumer product. Software will become much easier to develop as more and more operations are generalized and turned into "software-ICs" — a term which equates software objects with integrated circuits and suggests that pieces of software will simply be "plugged together" (MAX presents a useful analogy here).

Removing all external devices from the electroacoustic performance system proposed earlier goes a long way toward ensuring generality and longevity. However, as the computer industry continues to gather technical momentum and market coverage, there is no guarantee that a floppy disk or DAT backup tape will be decodable ten years from now. CDs have a longer shelf life but even that is probably less than one hundred years. It is inconceivable that in 2100, my programs will run on any computer being produced at that time. This is indeed troubling and I have no good solution to offer. It is ironic that my piano, built in the late 1920s will outlive my electroacoustic resources.

As unsettling as these thoughts may be, there are some new technologies which I believe present some interesting new opportunities for electroacoustic composers. Most of these are in the world of sound reproduction.

Surround sound

The rapid sales growth in home theater sound equipment suggests that the listening experience is very important to many consumers and, as these systems become more prevalent, audiences of electroacoustic music will certainly demand equal or better audio projection than they can produce in their homes. Two speakers will not be enough. The multispeaker approach of the tape composers follows the same logic — two speakers simply cannot provide the same sonic experience as many.

The most common format is "surround sound" which is usually specified as "5.1" channels but actually requires only four discrete audio signals. In consumer-grade Dolby Matrix Surround (offered on most commercial video tapes with stereo sound), an encoded two-channel signal is decomposed into four channels: front left, center (for speech mainly), front right; rear left and rear right are the same signal phase inverted (and possibly delayed). The five speakers are enhanced by the

addition of a subwoofer which takes a sum of the front signals and passes only the lowest octave (20–200 Hz) thus producing the remaining ".1" channel. This format is being challenged by several other emerging technologies such as the eight channel capability of digital video disks and multichannel MPEG audio compression.

There is an implicit invitation here for tape-music composers; if home movie audiences are prepared to invest in multichannel surround technologies to hear high quality movie sound, perhaps the home is the most promising target for tape music presentation. These developments further suggest that multiple loudspeaker arrays may also be a way to enhance live electroacoustic music performance though other factors must be taken into consideration such as the hall, the cost and the performer's access to the materials for rehearsal purposes.

3D audio

A technology appearing in more and more CD-ROM and games products is three dimensional (3D) audio localization. Several research efforts over the past decade such as (Kendall 1984) and (Bregault 1994) have clearly established the viability 3D audio localization for creative applications. Some sound cards for PCs already offer 3D hardware which the game developers have begun to exploit. The game development software released by Apple in March 1996 includes a function library for 3D sound which includes parameters to specify such things as the medium of transmission (e.g., dry air, fog, water). These are powerful tools which demand powerful computers and, in conjunction with new procedures for 3D graphics, promise to change user interface design significantly.

However, after several months of experimentation with 3D audio in the context of auditory display research (Pennycook and Breder 1996), it is not clear to me how to use 3D audio in a meaningful way in my own compositions. As the effects are most pronounced when listening with headphones, 3D may be better suited to works without live performers. Furthermore, the perception of the 3D effect (especially in the vertical plane) is highly dependent upon the listener's outer ear shapes. While it may work most of the time for auditory cueing of off-screen characters (the bad guy approaches from extreme lower left), I cannot see how such an imprecise technology could be reliably engaged in serious music composition. It is safe to assume, however that as market demand for 3D grows, this technology will mature rapidly.

Automatic audio monitoring

Anyone who has played in a loud, amplified band has experienced the problems of on-stage vs. projected audio. In cases where technicians can provide separate audio levels for the on-stage loudspeakers in addition to the audio mix projected

to the audience, these problems can be overcome with sufficient rehearsal and sound-check time. However, the travelling concert performer rarely has technical help and must hope that the sound he/she hears on-stage is complementary to the sound in the hall. A possible solution here is the use of adaptive audio feedback and automated mixing. One or more microphones are placed at selected seating locations in the hall to "listen" to the concert. At regular intervals (10–100 ms would suffice) the monitoring software or device sends audio level information (RMS per analysis window) and at a minimum, adjusts the audio output of the main speakers according to some thresholds. This simple version, essentially a dual channel compressor limiter, can be expanded to include real time spectral analysis which can be used to automatically adjust levels of selected frequency bands, but this assumes much more elaborate signal processing capabilities and an audio playback system with machine-controllable equalization functionality.

Spectral information for composition algorithms

The spectrum analyzer described above can also be applied to compositional processes. By monitoring the spectral properties of the soloist(s) in real time, changes in the overall dynamics and in selected frequency bands can be used to inform compositional algorithms of the acoustic properties of the solo instrument. This could be a very powerful tool in the context of improvised music, especially jazz derived styles, in which timbral shifts are more frequently engaged as expressive elements. A MAX object based on the Digidesign Sound Accelerator card was developed at the Center for New Music and Audio Technologies, UC Berkeley and released as an external object which produced real time, multiband level information and some initial experiments with the software proved very promising for my own research.

Another spectrum analyzer has been implemented at McGill University which does not require additional hardware. Sound is grabbed from the Sound Manager (audio inputs of the Macintosh) and at fixed intervals, the current rms power level of eight, 1-octave frequency bands is passed to the MAX object. Like the CNMAT system, the outlets of the object produce control data which may be used for any purpose within the MAX program. A higher resolution version of the program is under construction for Power Macintosh computers.

Wireless communications

The rapid growth of wireless networks and digital cellular communications systems will profoundly impact the entire information industry. Though wireless microphones and wireless MIDI products are relatively common today (though not cheap), as the wireless industry grows, the maze of cables and connectors on-stage

may be reducible to a few power cords and the loudspeaker cables. A much greater impact of wireless technology will be felt by composers of works for multiple music workstations. In conjunction with the wireless hardware advances will be a wave of new software products (and development tool kits) which will simplify the process of communication among several computers. This may not effect today's performers very much but there are some new horizons here in collaborative composition and performance which can only be imagined at this time.

CLOSING COMMENTS

In this brief essay, I have tried to isolate some of the key elements which shape the growth and dissemination of live electroacoustic music. I have also offered some short-term proposals which may be useful for composers, performers, teachers and even hall operators who are interested in promoting the genre. I am actively engaged in the implementation and testing these proposals in the concert hall and, in time, should have a much better understanding of the impact such actions may have. Finally, a glimpse at some new technologies which are emerging now suggests that many new and exciting developments in live electroacoustic music are imminent.

One matter remains unsaid, so far. If the music itself is weak or acoustically incomprehensible, no amount of simplification will engender interest in the work. Players, especially chamber music specialists, perform music which they believe audiences will enjoy and which will illuminate the musicality and technical prowess of the soloist. The best we can hope for is that the availability and accessibility of the works reach a point where performers and teachers will feel comfortable with the genre. Only by trying new works will players determine if the piece is suitable for their repertoire. They will certainly find a richly rewarding world where the refined compositional sensibilities of chamber music blend perfectly with the power and sonic richness of electroacoustic music. I am also certain that improvements to the quality of audio projection will permit these works to reside comfortably within mixed repertoire recital programs and that audiences will eventually welcome the shift in sonic perspective that only loudspeakers can attain.

Finally, composers normally exploit their resources to the fullest. But these tools, whatever they may eventually become, *must* be made accessible to composers, performers, instructors, hall operators and must be completely reliable in all settings. I often wonder if any of my interactive works will be performed when I am dead and gone. Perhaps this minor vanity alone is enough to have engendered many of these considerations and search for new solutions to these old problems.

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