CHAPTER
1

PSYCHOACOUSTIC PHENOMENA IN MUSICAL COMPOSITION

Some Features of a "Perceptual Geography"

MARYANNE AMACHER

Foreward Note and Update

I wrote ***Psychoacoustic Phenomena in Musical Composition:*** *Some Features of a Perceptual Geography* in 1977 and first presented it in 1979. (See *Announcement Abstract* p.14). This was my first attempt to describe some of the results I was discovering in the sonic investigations I was making at the time. I wanted to understand more clearly the implications of certain ideas which emerged from these discoveries in order to develop them more explicitly in the music I hoped to create.

Over the years I have written about such ideas in a far more readable, enjoyable, and vivid way! This first *perceptual geography* text reminds me of some prefaces the early Baroque composers wrote, which in their very detail now read with such an ancient "precious" quality. For example Viadana describing his introduction and development of "basso continuo"—figured bass which did not exist prior to this time; and Caccini in *Le nuove musiche* describing the wonders of "introducing music composed for a single voice accompanied by a single stringed instrument" in contrast to the multivoiced contrapuntal music of the time.... "The harmony of a single voice with a single string instrument with such power to move the passion of the mind as those madrigals ..." and Monteverdi, in the preface to *Madrigali guerrieri ed amorosi* "a opportunity of describing in music contrary passions, namely, warfare, entreaty, and death"—such emotions were without expression in the music of his time.[1]

I have always loved these prefaces because they so concretely describe musical features we take so much for granted today, yet were absolutely unique in the era of these composers who had such great desire to give them existence in their music! Although I never imagined sounding "Baroque," there is a similarity in the detailed descriptions of my writing!

1. Oliver Strunk, *Source Readings in Music History: The Baroque Era* (New York: W.W. Norton & Company) 1965.

Nonetheless I find my "ancient" *perceptual geography* text interesting because it reflects this very first period of my musical development, as I attempt to understand the "unformulated." I particularly like very much publishing it in *Arcana III*, because *Sound Characters*, a 1999 Tzadik release introduced for the first time on CD, music in which I specifically developed the *ear tone responses* referred to in this essay.

The observations in this text all refer to sonic perceptual features which I felt to be the most compelling when I began composing with electronic sound. They originate directly from my experiences, sonically and perceptually. It is important to understand that since I was able to work with electronically produced sound it was possible for me to make these discoveries, *experientially* before considering how I would develop them musically: I had unrestricted time to observe what I was experiencing which would be severely limited if working with instrumentalists. Remember, to enhance the so-called psychoacoustic responses in composing it is first necessary to learn to recognize them. And this can only be achieved experientially, unlike most music which can be imagined mentally without having physically experienced it. Thus it was never the use of electronic devices to produce the sounds which interested me.

More specifically of first concern: *How certain sounds are to be perceived in a sonic world becomes as important as the sounds themselves.* What perceptual modes they trigger—where and how they will exist for the listener—are as important in shaping an aural architecture as the acoustic information: frequencies, tone colors, and rhythms. For example, ***Ways of hearing***—how we locate, sense and feel sonic events—become the specific factors which characterize experience in immersive sonic architectures; how we particularize acoustic information to construct distinct transformative experiences.

That my "ears were emitting sounds" as well as receiving them, that is hearing other acoustically produced tones at the same time, was incredible to me, a totally unique amazing experience at the time! Even though I *knew* this to be happening, lacking any musical theories that explored such vivid *ear tone responses*, I had to question them to a certain degree. How to accurately describe these affects? Could they perhaps be illusions, hallucinatory phenomena? Thus my writing is somewhat timid, and also conservative mainly due to my critical MIT advisors who were concerned that the reader might possibly suspect these descriptions to be more a phantasm

coming from my head! Because there is the expression *additional tones* in traditional music theory I use it in the text to describe such *ear responses* which are not the acoustic tones written in the score or sounding in the room but are in addition to them. This is unfortunate! How much better if I had referred to them by their true name: *ear tones*. But at the time it was not the sensible approach for communicating these ideas. Now of course all this is different as a result of astonishing research being carried out all around the world!

I continued however, over the years to develop my music exploring such sonic perceptual responses as described in this text because these features were so fully audible and present to me, and to design a unique computer program to map and compare the "sound" of specific tone responses as they arise from different intervals and registrations. All the while there were no musical theoretical studies to support this kind work, or was I familiar with any further scientific evidence other than the acoustic studies I mention in the text by Roderer and Oster. Then the incredible news!

Update and Coincidence

In 1992 I read a remarkable short article *Ear's Own Sounds May Underline Its Precision—A Tiny Loudspeaker Inside the Ear* (New York Times) by Dr. William E. Brownell, of the Johns Hopkins University School of Medicine. A leading researcher in "otoacoustic emissions," or OAE, sound which is generated from within the inner ear, Brownell reported dramatically: "Physiologists are still marveling at the discovery that ears produce sound. It is almost as astonishing as if the eye could produce light or the nose produce odors." And further: "A person who fails to emit sounds from his or her ears in response to a test tone generally turns out to be deaf, or suffering from disease or the influence of certain drugs. Significantly this response disappears a few minutes after death. This, many scientists believe implies that the otoacoustic response is the result of ACTIVE SOUND PRODUCTION, NOT JUST A PASSIVE ECHO OF EXTERNAL SOUND.

But it was not until high speed internet that I became aware of the many advances in auditory research acknowledging this double role of ears in both receiving and emitting sounds, that the ear is not simply a passive receiver as had been assumed for so many years! And I discovered an astonishing coincidence with the writing of my "perceptual geography" text in

1977. David T. Kemp, Professor of auditory biophysics at the UCL Ear Institute in London presented the first official evidence of otoacoustic emissions in 1978 by demonstrating experimentally that sounds originating in the cochlea could indeed be recorded in the ear canal by fitting a microphone inside the canal and recording them. Imagine what a shock this was! All these years had gone by and I had not been aware of his investigation or results! How different it might have been if I had known of his work while I was making my first observations of "ear tones" in 1977.

Even more shocking is that thirty years had gone by since the very first proposal, that the ear contained an advanced amplifier mechanism which makes it an active amplifier of *its own sounds*, was introduced by the extraordinary Thomas Gold in 1948. His ideas were dismissed by hearing researchers of the time. As a result he left the hearing field where he had been pursuing the theory of hearing: how the inner ear works, to become an internationally revered cosmologist. A theoretical astrophysicist, Thomas Gold is considered to be one of the great original thinkers of the 20th century. His imaginative ideas frequently challenged established explanations in many different fields and thus stimulated many scientists to think more carefully about accepted paradigms.

In 1984 Gold writes in a paper *The Inertia of Scientific Thought.*[2]

> The theory of hearing which I proposed then involved an active-not passive-receiver, one in which positive feedback, not just passive detection is involved. We now have very clear evidence, after these thirty-six years, that indeed an active receiver is at work, but we still have not got a receptive group of physiologists who deal in this field. The medical profession still has not got a clue as to why 15 kilocycles should be coming out of somebody's ears.

2. http://www.suppressedscience.net/inertiaofscientificthought.html

The discovery of otoacoustic emissions took the hearing researcher community by surprise. In fact, they didn't believe it at first. When OAE's were discovered researchers were fascinated but nearly everyone assumed them to be a curious but unimportant byproduct of the ear and of no consequence to mainline theories.

It is now sixty years since Thomas Gold's initiating hypothesis and thirty years since David Kemp's demonstrated "ear tones" experimentally. Intensive research activity is being carried out in laboratories all over the world largely due to the medical advantages these investigations offer.

Numerous studies have shown that OAE's disappear after the inner ear has been damaged, so OAE's are often used in the laboratory and clinic as a measure of inner ear health: an ear that puts out strong OAE's at each frequency must have a strong cochlear amplifier and probably good hearing too. Because OAE's provide a simple, non-invasive objective indicator of healthy cochlear function they are widely used in newborn hearing screening programs. It takes only a minute to detect the sounds that signal all is well in the ear.

And a number of different types of ear produced sounds have been distinguished other than those which are stimulated from an outside tone; for example, SOAE's are those sounds which occur spontaneously in the ear and are not evoked by a stimulus tone. It is reported that in a very quiet space it is possible to hear the SOAE's of another person you are close to. Whereas it is of course the evoked type of ear response that we meet in composing.

Important recent work has been made by Brownell, Hudspeth, Ashmore, Mammano and many others. An interesting video demonstration: http://www.hhmi.org/lectures/webcast/ondemand/97webcast3/amplifier.html

The fact that the ears produce their own tones is now completely taken for granted by the scientific community. However, despite the widespread compositional interest in various psychoacoustic phenomena, such as beating tones and other phenomena this astonishing function of our ears is simply not yet acknowledged consciously by the musical community in theory or in musical composition.

This is a mystery to me! And very strange! Hearing plays such a critical role in composing, that recognizing and acknowledging the range of what our ears do in response to the music we create would seem to be particularly desirable to pursue more explicitly and understand further!

How many more years will it take to achieve this acknowledgement? Another sixty?

More details will be available at lunch. I'm afraid we haven't even made it to breakfast yet!

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THE MARY INGRAHAM BUNTING INSTITUTE OF RADCLIFFE COLLEGE
3 James Street
Cambridge, Massachusetts 02138

COLLOQUIUM
Maryanne Amacher
Institute Fellow
will discuss
Psychoacoustic Phenomena in Musical Composition:
Some Features of a "Perceptual Geography"

Tuesday, February 6, 1979 at 4:00 PM
First Floor, Agassiz House
Radcliffe Yard

The work isolates certain characteristics belonging to the so-called psychoacoustical phenomena: tone sensation we create in our ears and brain, in response to many of the intervals in music. These are known as "additional tones" because they are not the given acoustic tones, nor are they traditionally written in the score. However, because we "hear" and perceive them along with the given acoustic tones, they have long been considered a major part of all musical experience.

Generally regarded as "phenomena" the psychoacoustician knows about, rather than response tones the composer *induces* with the pitches he selects, academic music theory and criticism have yet to distinguish some of the more sophisticated ways such tones can enhance the development and experience of a musical structure. Although their existence is well established by modern psychoacoustics, "additional tones" are still regarded a subjective aspect in musical composition: something the listener creates, but *not* the composer, who, in fact, induces the existence of these tones, by the acoustic intervals he selects for his music. By his choice of musical intervals, the composer prepares for the existence of specific response tones that will be perceived along with the acoustic tones in the music, that will "sound" in the listener's ears and brain, rather than *in* the room: he "ghost writes" the scenario. "Additional tones," just as acoustic tones, may be considered a subjective aspect in the listener's musical experience, but certainly need not be considered a subjective aspect in the composition of music. In her Colloquium, Maryanne Amacher will describe her studies of these "additional tones."

Psychoacoustic Phenomena in Musical Composition: Some Features of a Perceptual Geography

Maryanne Amacher 1977

1.0 Summary of Perceptual Geography

A major part of all musical experience is the fact that we create "additional tones" in our ears and brain in response to many of the acoustic intervals in the music. Classical composers have certainly composed intuitively with these tone sensations, enriching harmonic structures, and orchestrations. And the same might be said for the practice of music in general, particularly good performances. Even though the existence of responsive tones are well established in modern psychoacoustics, they continue to be regarded as a subjective aspect of musical composition. Academic music theory and criticism have not yet confronted how "additional tones" can be developed *consciously* in the composition of music, i.e., their role in the *technique* of musical composition. +, Note 1

Our experience of these responsive tones sensations are more or less subliminal. My work involves bringing them to surface, removing the subliminal status, the perceptual glue binding them to the acoustic intervals. The

+ "Additional tones" are considered "phenomena" to be understood by the psychoacoustician, instead of "response tones" which are induced by the composer when he selects certain acoustic intervals. I suspect this is one reason why the kind of practical understanding needed for creating specific kinds of responsive tones in musical composition has not been technically developed.

Note 1. The existence of these tones affects the experience of traditional composers' work, as well as experimental music. In electronic music, I suspect such tones are often accidentally confused with timbre (by the listener and by the composer), and partially contribute to what might be perceived as a strange and confused sound quality in the music. In this case, human response tones are not recognized perceptually, in the composing from the acoustic tones. Many experimental composers, currently interested in creating what are commonly known as "beat phenomena", with traditional musical instruments, are composing their music to produce response tones in the listener, whether they are conscious of this or not. The limitation here is, because a sufficient theoretical foundation does not exist for distinguishing specific possibilities among the various perceptual phenomena, human response tones are primitively grouped under the classification "beat phenomena."

This often results in a music where acoustic tones function as *slaves* to produce response tones (the curious "beat phenomena" experienced here) when a more interesting interplay between the acoustic and particular types of response tones might be *distinctly* composed.

work seeks ways of composing with "additional tones," so that tones originating within human anatomy exist in their own right, i.e., become *perceptually* more than an accident of acoustic tones in the room, attain *conscious interplay* with them. To do this I have developed what I call a "perceptual geography," which allows me to prepare for the *existence* of these tone sensations, by *distinguishing* them in time and space, perceptually.

The response tones we create as a result of the acoustic space we are in, matter to me as a composer. Tones in the room affect our mind and our body. The latter respond by creating new tones. What I am calling "perceptual geography" is the *interplay*, the meeting of these tones, our processing of the given. I distinguish *where* the tones originate, in the room, in the ear, in the brain, in order to examine this map and to amplify it musically. I want to listen more carefully, to what are innate and perhaps even distinctly human capabilities. This involves developing a music which more clearly lets us "hear" some of these responses, lets us "know" that given acoustic intervals are indeed affecting responses in our ears and brain. It is a music which emphatically brings attention to what is happening to us.

With traditional musical instruments, the *experience* of *our* processing is more or less subliminal, because energy is distributed over such a complex spectrum. This aspect of the musical experience can be enhanced with the addition of simple tones, produced electronically, because they are capable of concentrating energy at certain specific frequencies. Simple tones allow us to present clearly the structure of the interval—the ratio characterizing the interval. This amounts to a "reinforcing" of something very basic, that we have previously "known" and experienced "less clearly" in music; the same interval given by two musical instruments would contain much more harmonic information.

I am sure that past composers understood much of this and would have liked to pursue it further. Today, this music can exist because of the use of simple tones, produced electronically, in musical composition, and can be developed because of the computer—and with the knowledge from modern research in musical acoustics—it is time to take these further steps.

In the music I am describing, superpositions created in ears and brain are reinforced. Tone responses can emerge from subliminal existence and become truly "audible" *recognizable* experiences. I use simple tones, selected purposefully for these reinforcement functions; musical instruments create the timbre of the tone structure, and relate specifically, in

melody, rhythm, pitch, close interval relationship, to tones and/or patterns being created in ears and brain. An interplay is cultivated between musicians and tone sensations. It is intricate. The musicians embellish, improvise with human-given tone responses.

It is a matter of composing—distinguishing ears and brain as different tone spaces, and creating musical dimensions for them. The composer "ghost writes" the scenario, prepares existence for tone responses in time, and space, perceptually. The selection of acoustic intervals may be determined now by choices made regarding particular tone sensations to be created in ear and brain spaces. Tone responses in ears and brain are no longer merely an accident of the acoustic tones compositionally, but can now play a critical part in the selection of those tones.

1.1 Relation to some of my recent work

For some time I have been exploring certain psycho-acoustical phenomena in my compositions, deliberately. These works examine different ways in which access to a perceptual geography can enhance the development and experience of a musical structure. The music I plan to develop involves a composition of perceptual space, much more detailed than any I have previously composed. In this music I will be combining the results of my work with the perception of dimension in (**a**) the acoustic space (sounding "within the room") with that of (**b**) and (**c**) tone sensations originating within human anatomy, which *are not acoustically* present in the room; produced internally by the listener, they are stimulated by given combinations of tones in the room; they exist in the ears and in the brain.[1,2]

Belonging to the traditional woodwork of musical composition and performance, there is no question of their reality—our mind-body creates them whenever we experience music. Considered a mysterious ingredient of music, they are sometimes called "additional tones."

1. Juan G. Roederer, *Introduction to the Physics and Psychophysics of Music*, Heidelberg Science Library, 1973.

2. Gerald Oster, *Auditory Beats in the Brain*, Scientific American, 1975.

These dimensions co-exist in all music, but (**b**) are more or less subliminal in traditional musical experience. We regard such "additional tones"—such as missing fundamentals and combination tones, as fall-outs, residues of the "real" tones. In composing, the "real" (i.e. the acoustic tone) is chosen and the others result; they are *accidents* we come to depend on. My work is in bringing response tones to surface, removing the subliminal

status, the perceptual glue binding them to (**a**). The work seeks ways of composing with response tones, so that (**b**) and (**c**) exist in their own right, i.e., become perceptually more than accident of acoustic tones in the room—attain conscious interplay with them.

My recent works, *Remainder*, *Labyrinth Gives Way to Skin*, *Listening At Boundary* are steps towards developing the proposed music. They explore situations at boundaries of perception: scenarios existing between acoustic space and mind interpreting pattern, subjective threshold, body resonance. I have developed this music intuitively so far by intense listening research—recognizing, identifying, attempting to understand implications of the various musical phenomena I experienced. I later found many of these to be characterized by events—superpositions resulting from given acoustic stimuli—taking place *within* neural and auditory anatomy, described best in the research of Roederer[1] and Oster[2], notably, specific interval (Roederer) and sound level (Oster) studies. Note 2

There is much more to do, however, and I could make these further studies (and compositional implementations) best at the Artificial Intelligence Laboratory, MIT, and at the Computer Music Program, Music Department, MIT, Cambridge, Mass.—as well as continuing past collaborations with musicians at Harvard University, and in NewYork City.

1.2 More details

I have found that my own discoveries fit closely with the distinctions given to "additional tone" phenomena of (**b**) and (**c**) by Roederer and Oster. They describe perceptual phenomena I had previously composed with "by ear." (I used a system of private metaphors to identify these musically, originally.) In composing I *distinguish* the given acoustic space in the room with the "tone spaces" of ears and brain (Roederer and Oster[1, 2]). My research involves a study of

Note 2. The composition of spatial dimension acoustically (sound "within the room")—composing a phrase so that some of the tones are experienced nearby, some at a distance, some locatable, some ambiguous, has continued to be an important parameter in my music. Since we are more or less without musical models for studying acoustic depth and sound localization, models have been selected from environmental spaces. One such space was a site at the Boston Harbor. Here, distant sound could be heard clearly and simultaneously with nearby sound—sound occurring near the microphone, installed on a partially open window facing the ocean. For four years the sounding space was transmitted directly "live" through an open 15kc Bell program channel to my studio at MIT—a way of learning, experiencing acoustic depth in detail, and in as many changing conditions—subjective and acoustic—as possible. I wanted to induce a *sense* for *sound dimension*, corresponding musically to the curiously subliminal sense for melody and phrase, perhaps acquired first, from playing a musical instrument, then surely, from hearing music around us much of the time. So I "played" the space using my mixer which received the "live" incoming space, at other times I listened to it in the many odd hours customary to music listening. I especially wanted to carry this "second nature"—a direct experience of *sounding spatial dimensions*—to musical instruments, harmonic structure and combinations of instrumental timbre with other sound spectra; and even more basically, to create an *experiential soil* for developing ways in which the perceptual geography of a musical structure may change over time.

intervals produced in the room (**a**) which stimulate additional tone sensations in the ears (**b**) and in the brain (**c**). One group of intervals I will be studying are those which Roederer refers to as "1st order superpositions." These originate in the cochlear fluids and result from interactions between overlapping resonant regions along the basilar membrane.

I find it useful, when "1st order superpositions" are stimulated, to think of the listener responding—not to the real world primary sources—but to certain EXTREMELY RESONANT INSTRUMENTS—*within* the anatomical structures of the inner ear. We "hear" tones, other than the given acoustic tones, being created in our ears, as the membrane vibrates in response to the given acoustic tones.

The second group of intervals in the study produce sensations of tone and/or pattern modulations which are *not* present in the cochlear fluids at all. These exist in the brain, originating from the interaction of neural signals, after they have been combined at the medullar or midbrain levels. The processing here is more intricate than the previous resonant responses. When "2nd order superpositions" are stimulated, we "listen" to what our auditory system—CAPABLE OF DETECTING EXTREMELY SUBTLE CHANGES IN THE FORM OF THE VIBRATION PATTERN—*perceives* as it responds to the given acoustic tones. This is a very special beautiful feature to consider! In effect we "hear" an *evolved sensitivity*, extracting information on details of the vibration pattern. (Subjective pitch originates here.)

Where in this anatomy, or perceptual geography, does the choice of perceptual mode enter the composition as a "conscious" musical parameter? Do we have purely neural melodies, or do we combine them with cochlear or combination tone melodies for a given phrase. In the proposed music, choice of an acoustic interval in (**a**) the room, will frequently be determined by the tone or pattern modulation this interval *produces* in (**b**) the cochlea or (**c**) the brain.+ For example, suppose we want to bring a tone x (98 Hz) to a tone structure we are composing. Consider the kind of local relations being developed between (**a**) (**b**) (**c**) dimensions. These many be offsetting a certain kind of tonal depth, or distinguishing adjacent melodic tones between (**a**) (**b**) **and** (**c**). Depending on what is

+ Occurrence of 1st order combination tones, no doubt enriches performance of traditional music, and contributes accidently to what is generally regarded as timbre in much electronic music. By the very nature of synthetic sound, 1st order phenomena can be pronounced. However, when there is no *conscious* interplay prepared by the composer to establish experience of (**a**) (**b**) (**c**) dimensions, what we get to perceive in such a case, is an odd noise-like modulation occurring in space (**a**).

being developed here x could sound as a tone produced by a musical instrument in (**a**); as a combination tone in (**b**) (resulting from an interval arrangement in (**a**); or be "projected" out of (**a**) and (**b**) harmony to "spotlight" (**c**), reinforcing interpretation of the missing fundamental.

Specifically, allowing the tone spaces of ear (**b**) and brain (**c**) to become auditory dimensions in their own right, rather than *adjuncts* of the given acoustic space, is what much of my work will be about. Acoustic tones in (**a**) may stimulate what happens in (**b**) and (**c**) spaces, but (**b**) and (**c**) can also be distinctly composed. This involves developing something similar to what we know musically as voice leading, so that a *recognizable interplay* in time occurs between (**b**) and (**c**) and the experience and structuring of sound in (**a**). Music creates an *existence* for (**b**) and (**c**) in time. In other words, we get to know them as dimensions of ongoing, *sonic* experience. We "listen" to their music—respond to the tones and pattern modulation melodies we are creating here, as these interact with acoustic tones in the room. Their existence in time and in the human anatomy, should indeed, affect choices of (**a**) tones.

A physicist might object: although all those "effects" happen, one can only produce them via tones in (**a**), so attempts to affect (**b**) and (**c**) will have side-effects. This is perfectly right. However, there are many techniques, in music, for focusing attention on some things and "masking" out others in the (**a**) space, and this is what much of a composer's skill is most basically about.

2.0 Musical Composition and Some Features of Perceptual Geography: Sketch of Some Detailed Studies for the Project

1st order combination tones become extremely interesting in terms of perceptual geographies. Within a certain frequency range, such tones may sometimes not "sound" as though they are being produced within the ears, i.e., exist entirely in (**b**) space, at all, (compared with another group of "tones" which distinctly does). They "sound" as though they are occurring in (**a**) space, in ambiguous room space, "in air", not localized. But what is particularly interesting, is that *because* such tones are only *apparent* to (**a**) space, not localized as an acoustic tone in (**a**) often is, a number of interesting harmonic and other musical advantages are present, and I wish to investigate these further.

Ear tones created within (**b**) space in my experience, not only seem

to contribute a special depth to the experience of sound in (**a**) space, but also allow one to make certain exceptionally distinct combinations of tones, close to each other in frequency, which if produced in (**a**) space *only*, i.e., in the *same perceptual dimension*, would mask each other, or become one timbre, rather than be experienced as completely distinct parts. Here, because one perceives what is actually happening "within" ear (**b**) to be happening in (**a**) space, there is literally not only "more room" for other tones in (**a**), (e.g., among non-stimulating tones), but one can compose very subtle adjacent relations without interference, because such *interplay* can exist between (**a**) (**b**) and (**c**). The "non-stimulating" tones in (**a**) are offset in an especially interesting way now; we experience them differently as a result of (**b**) and (**c**)—their "room presence" seems to be intensified.

For example, more specifically, I have experienced tone sensations and melodies stimulated by acoustic tones 1700 to 5000 Hz which sound as though they are "being created" directly, INSIDE THE EARS. It is not clear whether these are in fact combination phenomena, or some other kind of resonance. They are however, in sharp perceptual contrast to the *experience* of familiar combination tones characteristic to (**b**). For this reason they are extremely interesting to me. I have composed acoustic tones sounding in space (**a**), while at the same time another distinct part of the music is "sounding" as though "being created" within the ears (**b**). Again, the interesting non-masking phenomenon is present, and uniquely distinct parts are possible, with remarkable differences in sound level. For example, in one section, 3–4 kHz stimulating frequencies in (**a**) are very intense **fff**. Yet, at the same time a very distant and thin sounding flute, **ppp**, and at another time, whispering voices, both assumedly in (**a**) space, are completely audible, as distinct parts. This example also included the 2nd order pattern modulation (i.e. "the maker of shapes" described by Roederer. How much this may have contributed to maintaining the distinctly contrasting sound levels of **fff** and **ppp** at the same time, without the **ppp** being absorbed in the **fff** as part of texture or timbre, I do not know. But, in any case, one cannot do anything like this with the six classical orchestra, in which faint sound are usually "absorbed" by almost any loud combination.

3.0 Instrumentation allowing the proposed music to exist and be developed

Humans seem to need music. It is around us much of the time, and is *happening* to us. We may not be conscious of it being there, or that it is

stimulating certain specific sensorial responses. My work involves developing a music which lets us *know experientially* that given acoustic intervals are indeed affecting responses in our ears and brain, let us *hear* some of these responses vividly.

This music can exist because we are able to produce simple tones electronically, and can be developed because of the computer. Because ordinary instruments have very complicated spectral energy distributions, the experience of *our* processing is more or less subliminal, though it is a major part of the musical experience—our ears and brain creating the additional tone sensations and shapes to given acoustic intervals. This aspect of the musical experience can be enhanced with the addition of simple tones, produced electronically, because they are capable of concentrating energy at certain specific frequencies. Simple tones allow us to present clearly the *structure* of the interval—the ratio characterizing the interval. This amounts to a *reinforcing* of something very basic, that we have previously *known* and experienced less directly in music; the same interval given by two musical instruments would contain much more harmonic information. When simple tones are selected specifically, as the acoustic intervals for this purpose, superpositions being created in ear and brain are reinforced. Response tones can emerge from their subliminal existence and become truly audible recognizable experiences. It is a matter of composing—preparing for their existence in time and space, *perceptually*. The composer *ghost* writes the scenario. The selection of acoustic intervals may be determined now by choices made regarding particular tone sensations to be created in ear and brain spaces. Tone responses in ear and brain are no longer merely an accident of the acoustic tones compositionally, but now play a critical role in selecting those tones by the composer.

Programmable acoustic equipment is necessary for examining sufficient detail, range, and combining possibilities of the many intervals, needed to be compared for specific compositional purposes, and related to musical instruments in the compositions. The music I am describing can be developed through these kind of pre-compositional studies. Digitally controlled acoustic equipment is critical to this work, because of two important features: the precise tuning requirements, and most important this music can be developed only through direct auditory experience.

To study and compose with response tones, one must experience them! Many research hours must be spent listening and examining *the expe-*

rience of certain combinations of intervals. The piano made harmony easily accessible to composers; the computer now allows us to become familiar with response tones. (Perhaps it is because the complexities are more equally matched here—why we can begin to compose with complex human processing, previously considered *subjective*. With simple programs one can efficiently do this work—produce the many necessary tone combinations for pre-compositional study. Here, because of the incredible efficiency in producing these tones, one has the TIME for the very critical *listening*, *experiencing* part of the study. Being able to do this, with the kind of accuracy, scope, and time presently available, as a result of programmable acoustic instrumentation, is exactly why a detailed precompositional study, examining psychoacoustic phenomena can be made today, and why it was not possible to examine and develop such aspects of musical composition, consciously (and theoretically) ten years ago. (We did not have *the piano* to play, before we made music for orchestra.)

4.0 Orchestration of the Music; Scenario

One level of the music, most basic to the project description, consists of specific sets of acoustic intervals, composed of simple tones, produced electronically. These are composed to create particular superpositions in ear and brain spaces, and are often accompanied by musical instruments and other sound spectra for timbre. However, it is the specific function of the intervals here to initiate creation of particular ear tones and/or pattern modulation melodies in (**b**) and (**c**). Another group of tones are composed for the musical instruments. These relate specifically, in pitch or interval relationships, in melody, rhythm, timbre to tones and/or patterns our ears and brain will be creating in (**b**) and (**c**).

An interplay is cultivated between musicians and tone sensations. It is intricate. Frequently—subtle tunings, close interval relationships. Complementary timbres tinge to a greater or lesser degree. The musicians embellish, improvise with human-given tone responses.

Our responses to the basic intervals perhaps are distinctly human ones. They exist in all musical experiences. They are basic, mechanistic in that *they go on without us*—whether we *know* it or not. In the music I am describing, simple tones now bring attention to *what goes on without us.*

We *listen* to ***it***. Musicians weave tones around our response tones as they are being created. Energy is created in the interplay. ***It*** feels itself.

Grows an arm. Starts to learn. Rapport is cultivated. ***It*** gets smarter. A counterpoint exists: music explores what has been suppressed, and with its curious changes, strange levels of mood, mind, provokes new responses, our response to ***it***.

Right now our subtleties barely exist for us—*they go on without us*—like the "additional tones" adjuncts of our actions in the environment. We do not listen to them. They belong to the "machine" we dare not acknowledge. That wonderfully complex, gentle, subtle Gorgon, responding every moment, with its intricate abilities—mysterious beyond our comprehension—we dare not look. The riddle remains. One of human potential. "What is responding every moment for *us*, but we are not allowed to respond to *it*?" Image in stone? Man in control?

From the point of view of biological evolution, von Bekesy compared the basilar membrane to a piece of skin with an ENORMOUSLY MAGNIFIED "TOUCH" SENSITIVITY. I take the implication of this analogy very seriously. To evolve, we will create more consciously with such extremely sensitive endowments, increasing the subtlety in our *responsive energies*. We do not acknowledge our subtleties, much less appreciate them. So much in our environment requires *keeping them on* but says pretend it's not responding, don't let outside or inside touch you. (Music played at such intense levels, although primitive, represents a need to at least feel some of *this capability* in action.) To evolve with our sensitivities, we must learn to *feel with them*, in intricate subtle situations. The interplay between musicians and response tones with their corresponding shaping features is intended to stimulate rapport between dormant energies. I think we can approach some of these experiences, gently through music.