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How Players Adapt Psychologically to Their Acoustic Environment

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Introduction

Playing a musical instrument is a valued achievement in our culture. It is generally thought the quality of performance achieved reflects both the skill of the player and the nature of the instrument. But the interaction between player and instrument is only poorly understood. As Bowsher [1] noted, instruments have been developed and refined over the centuries with the application of craft knowledge but with little appreciation of the fundamental principles involved. Similarly the acquisition of playing skills is primarily achieved by a trial and error process guided by individual teachers' insights in the absence of well defined knowledge validated by scientific enquiry.

The nature of the player-instrument interaction

Musical instruments differ widely in the process underlying the generation of their particular sound quality and the extent to which the player can influence that sound in performance. Ortmann [2] observed that in the case of the piano, the pianist's skills are primarily exhibited in the player's touch which determines the choice of the level for individual notes, overall level, staccato-legato and pedal skills. By contrast instruments in the brass family are characterised by a far closer relationship between the player and the instrument. In brass instruments the player's lips function as a valve which modulates the air flow from the lungs into the resonant air column within the instrument. By virtue of their relatively high mass the lips play a far more significant role in determining the mode of vibration within the instrument than the equivalent reed based valve in woodwind instruments. Elliott and Bowsher [3] have presented evidence which shows how the brass player can vary the parameters of the regeneration process which governs the relation between the air flow, and the vibrations in the lips and air column over a wide range in response to artistic and acoustic requirements. They have shown that while the movements of the lips may be sinusoidal, the pressure changes injected into the instrument are rectified and are impulse-like. Thus the player can put a harmonically rich pressure pulse into the instrument which energises the higher partials in the instrument air column which are characteristic of the brass instrument timbre. Furthermore the player may use the resonant properties of the mouth cavity and create turbulence in the air flow to direct and enhance the harmonic content of the instrument's sound.

Determinants of instrument tone quality

The sound of musical instruments varies in respect of pitch, intensity and the tone quality. Tone quality or timbre is a crucial dimension of musical performance. In the history of music the tone quality of particular instruments and the performance of virtuoso players have acted as a major stimulus to composers. In the field of jazz and improvised playing the exploration of tone quality together with the use of inflected or vocalised styles of performance are an essential element of this form of musical expression. The physical determinants of timbre have been considered since the time of Helmholtz [4] who noted that the tonal quality of instruments was dependent on transient features of sound. The availability of the computer for the analysis and synthesis of instrument tones has led to a major clarification of the problem. Rissett and Matthews [5], along with others, have established the importance of the temporal envelope of an instrument's sound in determining the perceived timbre of the instrument. Furthermore it has proved increasingly possible to understand the temporal characteristics of an instrument's tone which may involve starting and end transients, a steady state spectrum and noise as well as tonal elements, in terms of the mechanism and process employed to generate the sound within the instrument. The operations underlying the perception of timbre by the player when performing or by the listening audience must be primarily directed at registering and categorising the transient structure of the sound. In that respect the perception of timbre and the perception of speech stimuli show striking similarities. The significant features responded to in speech stimuli are the temporal contiguity of critical acoustic events. Fry [6] argues that speech perception depends on the recognition of a pattern of relations which involve transitions between acoustic events and is relatively independent of the absolute value of the separate components. Reliable speech perception is achieved despite differences in the fundamental voice pitch, speed, quality of articulation, dialect, speech impediments and general style.

Feedback and the control of musical performance

One goal of a musical performance is to play so that the instrument produces a sound which is musically and artistically appropriate which can be heard by the audience. Thus we might expect that the player will continuously monitor his performance with regard to the sound quality. However, a number of pieces of evidence suggest that this might not be the most efficient strategy. The manual skills involved in operating musical instruments may involve the use of the muscles in the hands, arms, mouth and articulatory apparatus, chest and diaphragm etc. etc. The execution of coordinated skill movements is considered to be controlled by motor programs which employ Kinesthetic information to provide feedback and monitor muscle movement, the position of joints in the hand, tension in muscles, skin contact and pressure. The skilled musician who practices to a level of extreme mastery may be able to perform by relying on Kinesthetic feedback alone. However, the instrumental player who has to play a large repertoire may not attain this level of skilled organisation. Indeed, Moray [7] reports that the skilled performer will almost always use visual and auditory information when possible to control performance on manual tasks. Indeed, Deutsch and Clarkson [8] report that singers go out of tune when deprived of auditory feedback and this is no doubt true for all instruments in which pitch is controlled by the player's action. While the moment to moment control of pitch is obviously crucial for most players, active control of timbre may not be. Bruton-Simmonds [9] found that a group of classical musicians of international renown did not exhibit advanced ability in the area of timbre judgement. While one can call into question the validity of the test of timbre judgement employed by Bruton-Simmonds, it appears that the discrimination of complex sounds differing only in harmonic structure was not a major element underlying their skills of performing. Brown [10] suggested that the failure to find outstanding timbre judgement skills among virtuoso players may indicate that the development of skills which allow great speed and accuracy of movement in performance precludes the moment to moment use of feedback control based on complex auditory perception. In fact, the execution of musical phrases composed of many short notes produces a perceptual event with properties quite distinct from those exhibited by long sustained notes which can show the instrument timbre to the full.

The differing perspectives of players and listeners

It was argued at the beginning of this paper that developing the ability to perform on a musical instrument will involve developing techniques to control the instrument's tonal quality or timbre. The material reviewed in the immediately preceding paragraph suggests that the timbre used by a player arises from well established playing techniques which are not generally open to modification on the basis of auditory feedback during the course of a performance. In the longer term, with practice the player can develop and enhance his ability to control timbre. One interesting feature of some instrument families is the difficulty the player may have in monitoring the output of his instrument. Once again the brass family provides a nice example. As remarked earlier the brass instrument player is coupled to and directly participates in the operation of the instrument while playing. The action of the lips vibrating in combination with the air column will be transmitted through the cheeks and skull to the ears. Similarly the passage of air through the mouth cavity may excite formant frequencies. Thus the sound and vibrations generated within the head could affect the perception of airborne sound arising from the instrument. In practice our capacity to selectively attend to spatially separated sound may limit this problem. However although the player can attend to his instrument's airborne sound, the player operates his instrument behind or below the bell which radiates sound energy out of the instrument. Thus the player will only hear the radiated output of his instrument indirectly, partially delayed and transformed by reflection and transmission. Presumably during the course of acquiring a playing skill the instrumenalist learns with advice from his teacher when he is achieving an acceptable instrument sound within a representative auditorium. The player must retain an image or some representation of what the instrument sounded like from behind the instrument. Similarly the player must retain a memory representation of the precise playing techniques used to achieve the desirable instrument sound. The situation is to a degree similar to that of the speaker or singer whose perception of their own voice and in particular the frequency balance will differ from that heard by a listening audience. During training singers have to discover how to produce a voice which carries over an orchestra and out into the auditorium. Singers achieve this by the use of the singing formant described by Sunberg [11]. Singers are able to increase the spectral energy in a region between about 2,500 and 3,000 Hertz. The resulting increase in perceived power of the voice arises presumably because the position of the singing formant coincides with the frequency at which the ear is most sensitive. Fortunately perhaps the brass instrument player does not have to put up with the curious situation of the speaker or singer who has the sound generating and shaping mechanism incorporated in the same structure which incorporates the sound perceiving system ie the ears. In practice singers can make use of head cavity resonance as an internal cue on the basis of which to monitor and control their vocal quality. When the brass player sets out to monitor the output of his instrument to explore tonal quality, the sound achieved could be influenced by the structure of the standing waves set up in the playing room. Thus if he is setting out to devise a playing technique which will yield a bright brassy tone, which is said to be associated with significant energy in the higher partials, he needs to be aware of this factor. Movement within the playing space will alleviate the problem. Similarly introducing change ie transients into the tone could be used to reveal the structure of the spectrum. Leipp [12] has published spectrograms of notes produced by virtuoso players. In the case of the one second trumpet note spectrogram presented by Leipp, while the note shows a high overall stability with time, the spectrogram does show periodic disruption when the energy in each spectral band increases and there is slight pitch change. These periodic disruptions may be signs of the mechanism underlying timbre control at work.

How do players adapt psychologically to their acoustic environment?

The material I have reviewed above addressed the question of what is the nature of skill available to the player of a musical instrument. I have considered how the player might organise and monitor the execution of the manual components of playing skills and how he will perceive and control the sound of his instrument. It seems likely that at an advanced level of competence, the player will control his performance on the basis of Kinesthetic information. He will be able to produce the desired tonal qualities from his instrument by having previously learned what playing techniques to employ to achieve a desirable sound for one or many performing spaces. If he moves to a playing space which does not provide the expected reverberant feedback then he may respond by changing his timbre. An experiment designed to observe this process at work will be reported.

References

1] BOWSHER, J.M. 1980 The physics of brass wind instruments. Endeavour, New Series 4, No 1.

2] ORTMANN, O. 1962 The physiological mechanics of piano technique. New York: Dutton.

3] ELLIOTT, S.J. and BOWSHER, J.M. 1982 Regeneration in brass wind instruments. Journal of Sound and Vibration, 83, (2).

4] HELMHOLTZ, H. 1885 Sensations of tone, London.

5] RISSETT J.C. and MATTHEWS, M.V. 1969 Analysis of musical instrument tones. Physics Today, 22, 23-30.

6] FRY, D.B. 1970 Speech reception and perception, in New Horizons in Linguistics. Penguin.

7] MORAY, N. 1981 Feedback and the control of skilled behaviour, in Human Skills edited by Holding, D.H., Wiley and Sons.

8] DEUTSCH, J.S. and CLARKSON, J.K. 1959 Nature of the vibrato and the control loop in singing. Nature, 183, 167-8.

9] BRUTON-SIMMONDS, I.V. 1969 A critical note on the value of the Seashore measures of musical talent. Psychologia Africana 13, 50.

10] BROWN, W.G. 1979 The Musician, in The Study of Real Skills. Vol 2 edited by Singleton, W.T. MTP Press.

11] SUNDBERG, J. 1977 The acoustics of the singing voice. Scientific American, 236, 82-91.

12] LEIPP, E. 1971 Acoustique et musique, Paris: Masson.