Angelo Anastasio
Nicholas Bussard

Mouth Air Pressure and Intensity Profiles of the Oboe

MUSICIANS KNOW THAT some musical wind instruments take more mouth air pressure to play than others, and that notes of higher frequency on some instruments take more air pressure than notes of lower frequency. It is also known that the higher notes of some wind instruments are not as loud as lower notes, and that adjacent notes on the same instrument may differ in loudness. The literature reveals that there has been little precise measurement of these factors by performers and teachers. Of the literature consulted, there was only one account of a measurement made of the correlation between mouth air pressure and loudness.[1] The unwritten estimates of air pressure and loudness offered by performers and teachers are not only equally lacking, but are inaccurate in estimating mouth air pressure. A number of performers, including professionals, have made approximations of how much pressure is required to play wind instruments. Their estimates ranged from 20 to 90 pounds per square inch (psi). However, of those tested on a pressure gauge, none of them could produce more than 3.5 psi, and some produced less than 2.5 psi. These estimates did not differ from those of nonmusicians. It is interesting to note that neither the musician nor the nonmusician would say he could inflate an automobile tire, although such is implied in a mouth air pressure of 20 psi or more.

Given the basic role of mouth air pressure in playing wind instruments, it seems strange that so little systematic knowledge can be found, and that so much discrepancy exists between belief and substantiated evidence. In view of this, it was decided that a study of mouth air pressure and of loudness would be conducted, as these two phenomena are related.[2] Mouth air pressure was easily measured by means of a tube

[1] Robin Gregory, *The Horn* (London: Faber and Faber, 1961), pp. 114-116.

[2] This study was made possible by a grant from the Bureau for Faculty Research of Western Washington State College, Bellingham. Lowell Eddy of the chemistry depart-

connected to a pressure gauge and placed in the corner of the mouth where it did not interfere with playing. Loudness, a psychophysiological phenomenon, is difficult to measure.[3] The difficulty is increased when the listener is also the player of a wind instrument, and hence is both sound source and listener. Since intensity can be measured in decibel units and is generally similar to loudness, it was measured in this study instead of loudness.

The oboe, a soprano double-reed, conical-bored instrument, was used for this study. Six conservatory model oboes of five different makes were used. Three of the instruments were made of wood and three of plastic. The use of several instruments was intended to avoid the idiosyncrasies of any single instrument.

Four performers participated in the study. Two of them had accumulated twenty-two years of experience in playing the oboe, and played on instruments with which they were familiar. The other two performers had played the oboe for less than two years, although they each had had ten years of experience in playing other woodwind instruments. For this study the less experienced performers played on instruments with which they were not familiar; this was done to minimize performer control. The performers were thus grouped in two categories: more experienced players performing on instuments familiar to them and less experienced players performing on instruments unfamiliar to them.

It was decided not to hold the reed as a constant factor, since this would be difficult, if not impossible. The oboe reed is perhaps the least durable and least dependable of all reeds due to its small size and the thinness of its vibrating edges. A reed may change characteristics during a performance and may also change when it is not in use. The oboe reed is found in a wide range of sizes, shapes, types of cut, and stiffnesses because most players make their reeds according to their own specifications. A similar range of variation is found among commercial reeds. The wide variety of reeds in use is reflected in this study. Fourteen reeds of seven different types (four commercial and three performer-made) were used.

The two more experienced players used fourteen reeds—four commercial types and two performer-made types. One of the commercial reeds was made of a plastic impregnated fiber and was considered barely playable because of its stiffness. Four samples of one commercial brand obtained for the experiment were too soft to be played and were dis-

ment assisted with techniques of air pressure gauges. Loren Webb of the speech department and Allen Eaton of Educational Media Center assisted with intensity measurement and acoustical problems. David Mason of the biology department, Phillip Ager of the music department, and Edward Neuzil of the chemistry department gave advice and assistance in various aspects of the interdisciplinary study. Robert Riggs and Eric Brewster participated with the authors both as performers and in conducting the experiments.

[3] Stanley Smith Stevens and Hallowell Davis, *Hearing, Its Psychology and Physiology* (New York: John Wiley and Sons, 1938), chapter 11.

carded. The two less experienced players were not able to use this range of reed variation. They used twelve reeds—three commercial types and two performer-made types. The commercial reeds were reworked to make them less stiff and more responsive, making them in effect different reeds.

For this study the notes of the D major scale from D^4 to D^6 were selected. The full chromatic range of the oboe will be included in future studies, but the difficulties of handling too much data in a preliminary study made it advisable to set limitations. The two-octave D major scale contains an adequate number of notes and range of registers. It includes: (1) the characteristics of the low register, (2) the characteristics of the middle register, which is played with the same fingering as the low register plus various octave keys, (3) the break in fingering from the low to the middle register (B^4 to $C\sharp^5$), and (4) the characteristics of the high register with its cross-fingerings ($C\sharp^6$ to D^6), as shown in Figure 1.

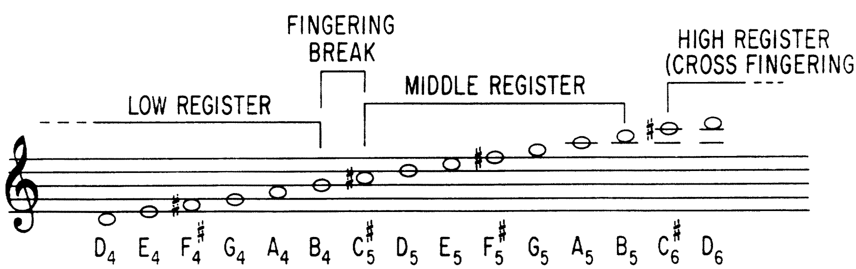


Figure 1

Air pressure was measured on a Wallace and Tiernan Air Pressure Gauge, Model #FA 145, calibrated in twentieths of a pound. Pound measurement rather than mercury or water column equivalents was used since musicians are more familiar with it. A moisture filter of calcium sulphate was utilized to protect the gauge mechanism. A flexible tube connected to the gauge was inserted by the player in the corner of his mouth. This did not interfere with the playing of the reed instrument, and the player became accustomed to the tube in a short time.

Sound intensity was measured on a General Radio Sound-Survey Meter, Type #1555-A, set at Weighting Network B. The meter was placed approximately two feet from the oboe with the microphone at right angles to the instrument. The level control was set at 85 for some trials and at 90 for others. Since the profile produced by intensity differences from note to note was of primary interest, intensity was not measured from a reference point such as the hearing threshold. Thus, all reference to decibel readings in this study is the difference between the highest and lowest intensities of notes played.

Frequencies of the notes played (vibrations or cycles per second) were measured on a stroboscopic device, the Conn Strobotuner, Model ST-6, calibrated to the equal-tempered scale.

Experiments and Data

Data were obtained under three sets of conditions:

1. Mouth air pressure was measured while intensity was held constant by referring to the intensity meter.
2. Intensity was measured while mouth air pressure was held constant by referring to the air pressure gauge.
3. Intensity and mouth air pressure were measured while the performer played the notes in tune by referring to the Strobotuner. At the same time, the player subjectively maintained a constant loudness without referring to the intensity meter.

For the experiments, the performer played two octaves of the D major scale as slowly as required by the observer who recorded the necessary measurements of intensity and/or mouth air pressure. The readings recorded after each playing of a two-octave scale are referred to as a run in this study.

As the performer played the ascending D major scale, he was instructed to hold intensity constant until the air pressure reading for each note was recorded. Intensity was held constant to minimize the player's control of pressure. The performer selected a level of loudness that he considered natural and comfortable for him. He then maintained this level by constantly referring to the intensity meter. Seventy-four runs of this type were made.

The performer then was directed to hold mouth air pressure constant while the intensity for each note was recorded. Air pressure was held constant at .35 psi as this was the lowest pressure at which some stiff reeds and some high notes would respond. A total of eighty-eight runs in this category were made.

The performer was then asked to check each note of the D major scale with the Strobotuner. This was done to ascertain the effect of playing in tune. Since it was not possible to play all the notes in tune when either pressure or intensity was held constant, it was necessary to conduct this experiment. Each performer selected and attempted to maintain a middle level of loudness (mezzoforte) without reference to the intensity meter. Both mouth air pressure and intensity readings were then recorded. Seventy-seven runs were made.

Analysis of Data

Mouth air pressure was measured in hundredths of a pound per square inch (psi). Intensity was measured in decibels. Only the differences between louder and softer sounds (greater and lesser intensities) were measured, not total decibel measurements. The dotted lines in Figures 2, 3, 5, 6, and 7 indicate one standard deviation; about 68 percent of the measurements made on each note fall within these dotted lines. All other lines in Figures 2-10 are mean averages.

Mouth Air Pressure

The mouth air pressure used in playing the oboe was measured under two sets of conditions. The first measurements were made with the intensity held constant; the results are shown in Figure 2. The second

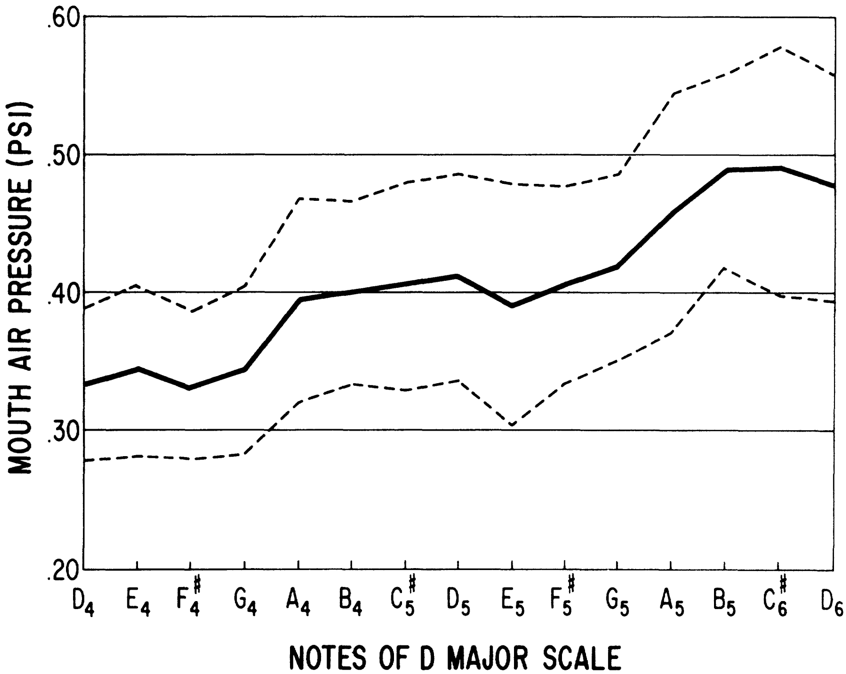


Figure 2

set of measurements were made with mechanical checking of frequency and subjective control of loudness; the results are shown in Figure 3. A minimal amount of performer control of mouth air pressure can be assumed in both experiments. When the player held intensity constant, he used pressure primarily to maintain the intensity level. When he subjectively held loudness constant and checked frequency on the Strobotuner, he indirectly controlled pressure in maintaining an even level of loudness. However, he also had to check frequency with the Strobotuner and may have used pressure as well as embouchure to do so. Hence, pressure was used for a double function in this experiment: playing in tune and maintaining a constant level of loudness. Despite the different uses of pressure in the experiments and the variety of combinations of oboes, reeds, and performers used, the pressure profiles of Figures 2 and 3 are very similar, Figure 3 being slightly higher. It is

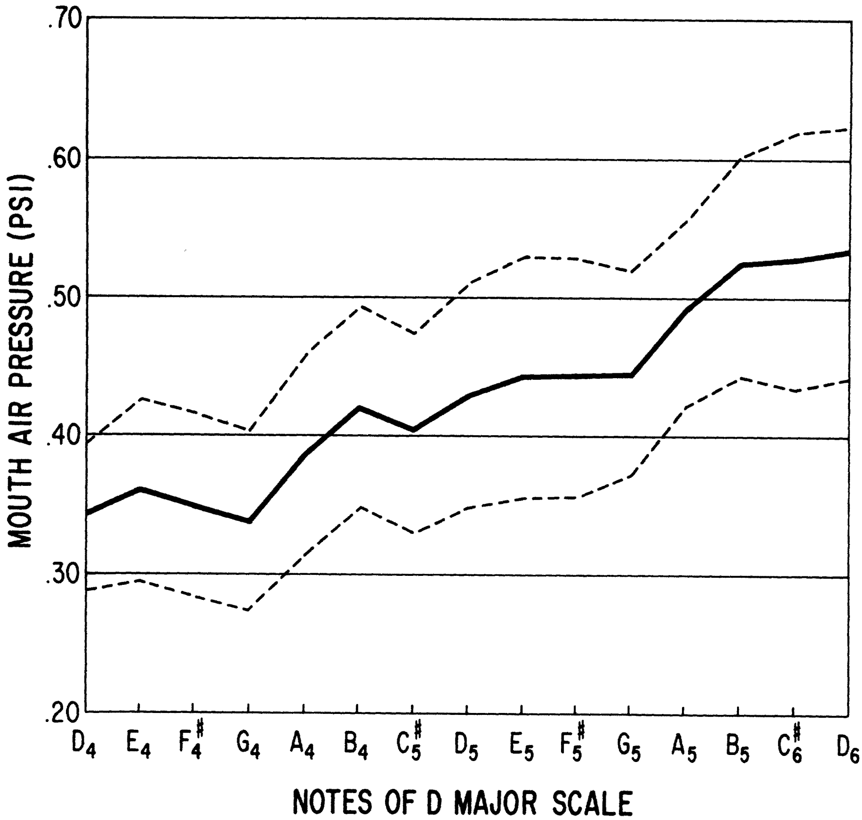


Figure 3

safe to assume from this that there is a characteristic mouth air pressure profile of the oboe, a basic requirement that the player must meet in order to play the instrument effectively. Figure 4 shows this profile, which is an average from a total of 151 runs.

The characteristics of the oboe with regard to mouth air pressure requirements may be inferred from Figure 4. It is obvious that as the player ascends the scale more pressure is required, but the pressure rise is not even. The air pressure for the notes D^4 to G^4 is fairly level. There is a sharp rise in pressure between G^4 and B^4. It was surprising to find little pressure difference between B^4 and $C\sharp^5$; different pressures might be expected here because of the change of fingering, change of tube length, and change to overblowing. The air pressure profile of the middle register is almost identical to that of the low register, although it is at a higher pressure level. The profile is fairly level from D^5 to G^5, shows a rise from G^5 to B^5, and is level from B^5 to D^6. Incomplete data in later studies suggest that the notes below D^4 have about the same pressure requirements as D^4, and notes above D^6 would require about the same or a slightly higher pressure than D^6.

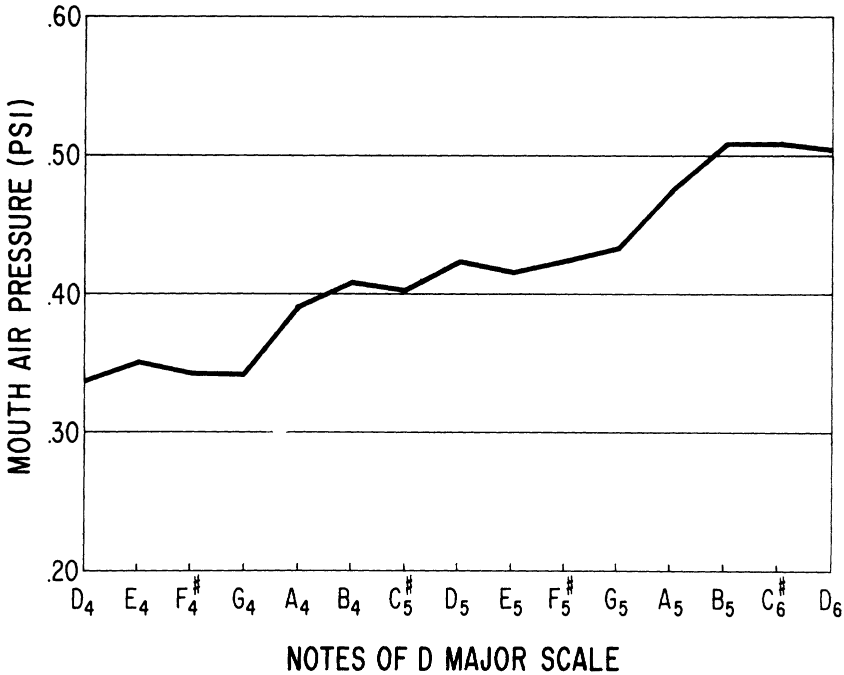


Figure 4

Probably no two oboes have exactly the same air pressure profile. None of those tested did, including the two of the same make, but the average profile serves as a guide in determining the profile of any oboe. For example, one of the oboes tested indicated a rise of .12 psi between G^4 and A^4 as compared to a rise of .05, .04, .03 psi, and a drop of .02 psi in the other instruments. With the rise of .12 psi there is a possibility that the A will be softer and sound at a lower frequency or be flat in musical terms unless the player raises the pressure or otherwise compensates when going from G^4 to A^4. Conversely, if he does not lower the pressure in moving from A^4 to G^4, he may overblow, and the G may be louder and sharper than intended, or the reed may choke and not sound. Thus a knowledge of air pressure requirements and the profile of an instrument is useful to the performer, teacher, acoustician, and instrument designer.

As noted above, the role of the reed in this study was not explored. The stiffness of the reed affects the pressure profile; stiffer reeds require more air pressure to sound and give a generally higher pressure profile than softer reeds. On the basis of this experiment, it was determined that plastic instruments take less pressure to play than wood instruments. This may be attributed to differences in smoothness of the bore surfaces.

There were differences in pressure profiles of the performer playing on several instruments. The more experienced performers used lower pressures throughout the range of the instrument than did the less experienced players. In addition, each player had his unique air pressure profile as the result of certain physiological factors.

The high estimates musicians and nonmusicians made of the mouth air pressure that they can produce or that is required to play wind instruments was not confirmed. In this study, the pressure used to play the oboe ranged from .20 to .70 psi. Other experiments now in process indicate that a pressure of 1.5 psi is possible on the oboe in the upper register, but this may be close to the limit. Finally, no one who tried either with or without playing an instrument was able to register more than 3.5 psi with the glottis open, or more than 4.5 psi with the glottis closed. These findings on air pressure were in the range of pressures recorded in studies of similar or related topics. Bouhuys recorded a mouth air pressure of about 60 mm of mercury (1.2 psi) for woodwind performers and a pressure of about 160 mm (3.1 psi) for brass performers. He also stated that pressures of up to 200 mm of mercury (3.9 psi) may be developed.[4] In a study of the relationship between mouth air pressure and oboe frequencies, Stensager recorded air pressures of 48 cm of water (.9 psi).[5] However, *Guinness Book of World Records* mentions a trumpeter who can "generate an internal pressure of 24 pounds per square inch."[6] If this is not an error, it indicates an upper limit of mouth air pressure beyond the authors' experience.

Intensity

Intensity was also measured under two sets of conditions. In the first instance, pressure was held constant. In the second, the frequency of each note was checked by the Strobotuner while the performer subjectively controlled loudness. When the performer played with mouth air pressure held constant, there was minimal pressure control of loudness and intensity. The resulting intensity profile, shown in Figure 5, is characteristic of the oboe to the extent that performer control has been minimized.

The intensity profile of the oboe shown in Figure 5 shows a fairly regular decrease in intensity from D^4 to B^5, the range of regular fingering, with the exceptions of E^4, E^5, and D^5. The E's were particularly troublesome, being louder and measuring greater intensity than the other notes of the scale. The rise in intensity between B^5 and D^6 may

---

[4] A. Bouhuys, "Breathing and Blowing," *Sonorum Speculum*, No. 13 (n. d.), pp. 1, 5.

[5] Eugene F. Stensager, "An Investigation of Some of the Factors That Control Fine Pitch Manipulation on the Oboe" (Master's dissertation, University of Washington, 1957).

[6] *Guinness Book of World Records* (New York: Sterling Publishing Company, 1966), p. 171.

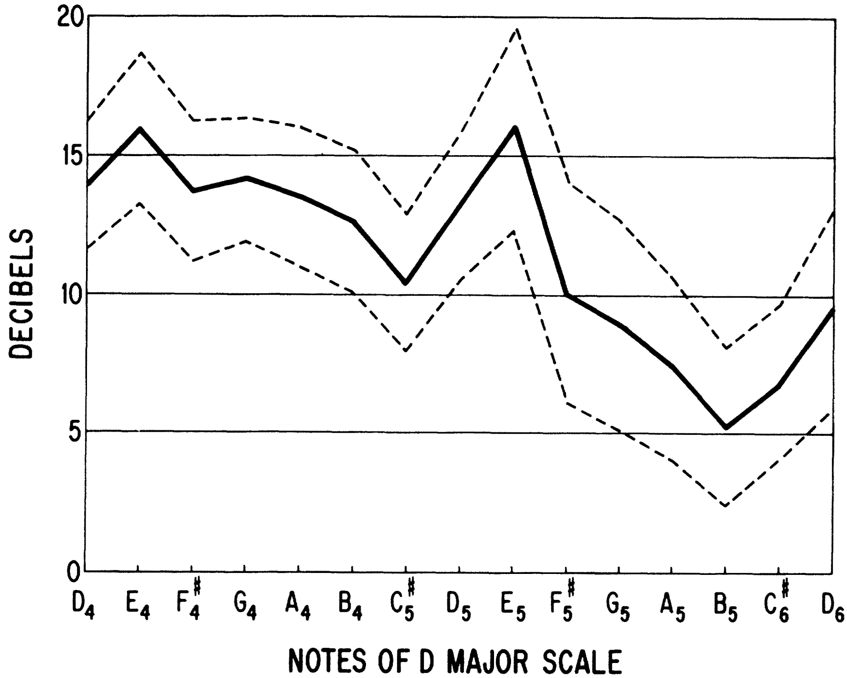
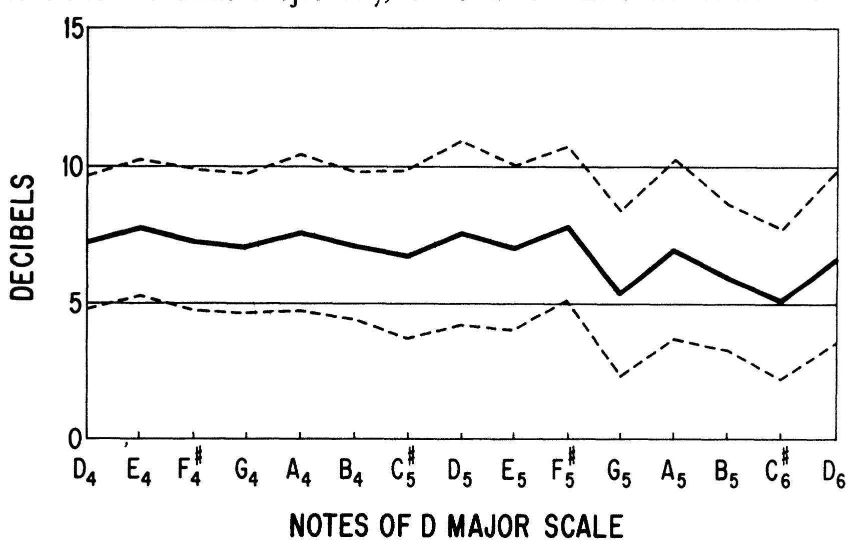


Figure 5

be related to acoustical differences introduced by the cross-fingerings of C♯[6] and D[6].

When performers held frequencies constant with the Strobotuner and controlled loudness subjectively, there were differences between the



more experienced and less experienced performers. The more experienced performers kept intensity (and presumably loudness) fairly constant, as shown in Figure 6. The less experienced performers produced the intensity profile shown in Figure 7. A comparison of the three

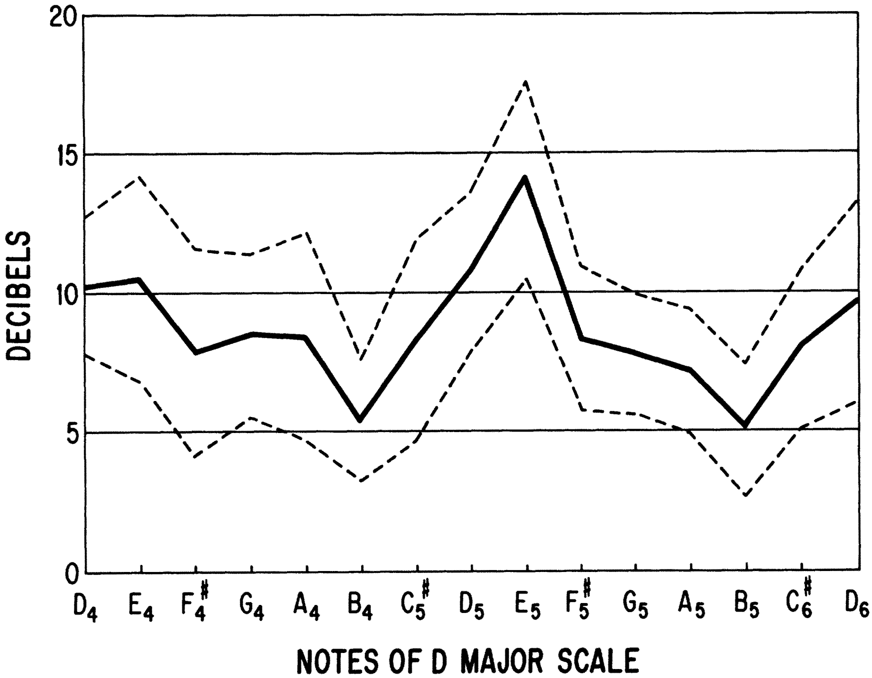


Figure 7

intensity profiles in Figures 5, 6, and 7 is shown in Figure 8. Note that all players leveled the intensity profile by reducing the intensity of the notes from D^4 to $F\sharp^5$. Between D^4 and A^4 there is not much difference among the four players, and the differences may have at least a partial explanation. The higher intensity of D^4 may be due to its being the first note played in each run. Thus it may have been attacked more firmly by the less experienced performers because low notes are more difficult to initiate than the higher notes. On B^4 the instrument is held only by the thumbs and the forefinger of the left hand; it is a relatively awkward position and the player may tighten his lips to help hold the instrument, thus muting the sound and lessening the intensity of this note. An additional variable may be introduced in the playing of B^4 if the player anticipates the following $C\sharp^5$, which requires the movement of seven fingers in precise coordination. E^4 and E^5 are obviously troublesome notes, and it is not surprising that less experienced players should produce high intensities. It should be noted that the differences between the more and less experienced players shown in Figure 8 are not as

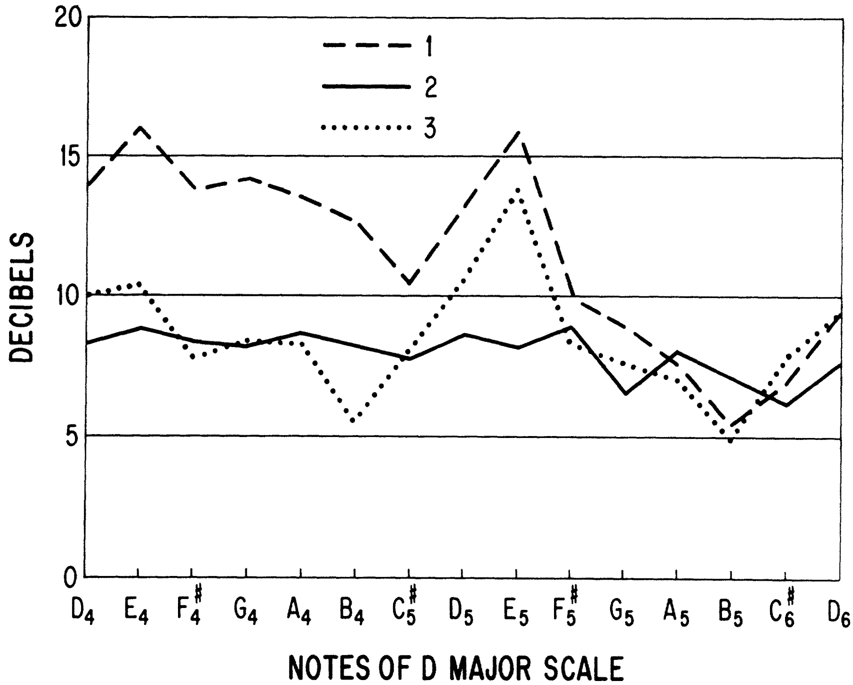


Figure 8

great as the visual depiction may indicate. A difference of five decibels would be audible to a trained musical ear, and three decibels might not be discerned by an untrained ear. The only point where there is a difference greater than five decibels is at E^5.

The opinion of the performers during this study was that a correspondence between loudness and intensity does exist in the oboe. The E's which measured a high level of intensity, were also loud notes, and the decreasing intensity of $F\sharp^5$ to B^5 paralleled a noticeable decrease in loudness. The results obtained by the more experienced performers in correlating loudness and intensity in this study and in later experiments suggest that loudness and intensity may be closely related down to the lowest note of the oboe, $B\flat^3$.[7]

As with air pressure, each oboe, reed, and performer had a different intensity profile. The extreme range of intensity measured in this study was twenty decibels.

A comparison of the mouth air pressure profile of Figure 4 and the intensity profile of Figure 5 is shown in Figure 9. This summarizes and

[7] Harvey Fletcher, *Speech and Hearing in Communication* (Princeton, New Jersey: D. Van Nostrand Company, 1953), pp. 188-189. Fletcher showed that loudness and intensity levels were equal for the frequency range 500 to 5,000 Hz; this includes the range of the oboe above B^5.

confirms quantitatively the opinion that musicians have of the inverse relationship between mouth air pressure requirements of the oboe and the resulting loudness, to the extent that loudness is approximated by the measurement of intensity.

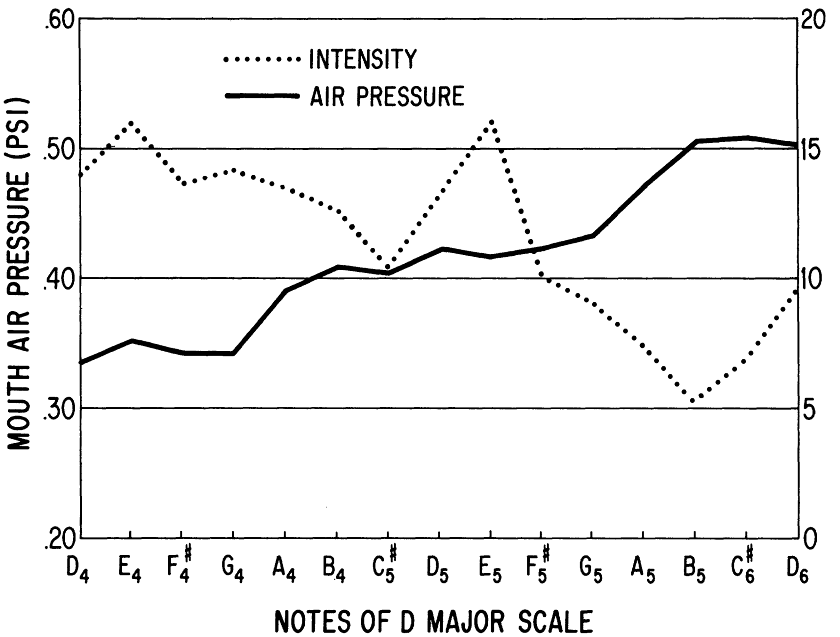


Figure 9

Comparison of Frequency and Air Pressure Profiles

An experiment to measure frequency with either pressure or intensity constant was not conducted because the measuring device, the Strobotuner, was graduated only to forty cents (hundredths of a semitone). Stensager, in an earlier work, made a study of factors affecting frequency control of the oboe.[8] He devised an oboe-playing machine equipped with an artificial embouchure and mechanism for controlling air pressure, and used the Stroboconn, a more versatile instrument, to measure frequency. In one experiment he measured the frequencies of certain notes from nine different oboes that the oboe-playing machine could sound.[9] Embouchure pressure was constant, and air pressure was constant at 32 cm of water (about .45 psi). This contrasts with the experiment reported herein in which frequency was held constant and air pressure was measured. For comparative purposes, those notes of the D major scale that were produced by the Stensager machine were selected and the results for the nine oboes were averaged.

[8] Stensager.
[9] Stensager, pp. 37-50.

In another experiment, Stensager analyzed and quantified a common view of wind instrumentalists: when mouth air pressure on the oboe increases, frequency rises; and when air pressure decreases, frequency descends.[10] This parallel relationship between pressure and frequency is shown in Figure 10, which contrasts the air pressure profile of Figure 4 (continuous line) with the frequency profile of the Stensager study (broken line). Because frequency was held constant and pressure measured in the present study while pressure was held constant and frequency measured in Stensager's work, there should be inverse movement of pressure and frequency from note to note in Figure 10. If the

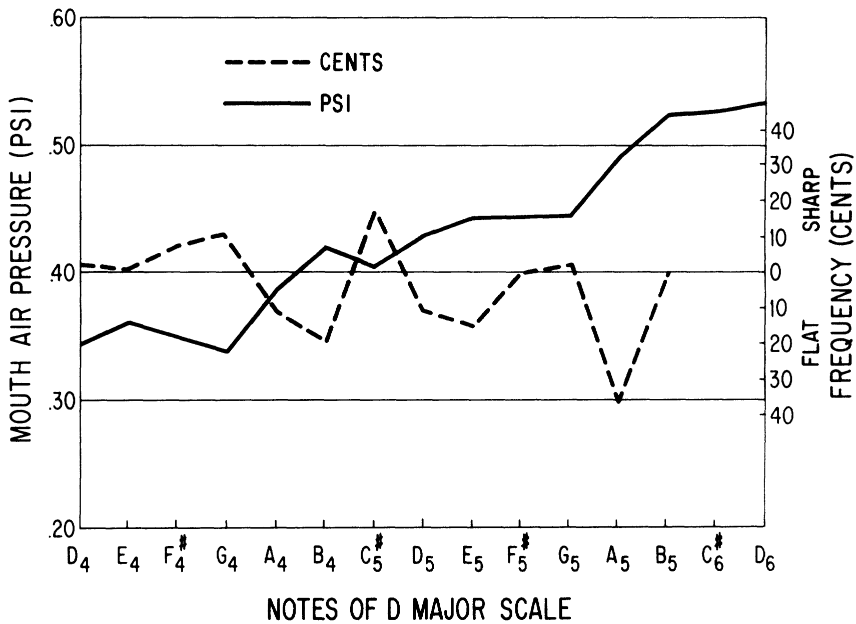


Figure 10

air pressure profile is supposed to rise to maintain frequency in the present study, then the frequency profile made with pressure constant in the Stensager study would have to descend because pressure is not enough to maintain frequency. The reverse holds also. This inverse relationship is seen between all adjacent notes in Figure 10 except between E^5 and $F\sharp^5$, $F\sharp^5$ and G^5, and A^5 and B^5. This correlation of data obtained under different experimental conditions, including distortions introduced by averaging the pitch profiles of nine oboes, and differences in players, primarily in embouchure control, playing machine, oboes, and reeds, is hardly conclusive but does indicate that further research is promising.

[10] Stensager, pp. 50-52.

Conclusions

1. The oboe has a characteristic mouth air pressure profile, which was obtained first with intensity held constant, and then with frequency held constant and loudness controlled subjectively.

2. The oboe has a characteristic intensity profile, which was obtained with air pressure constant.

3. The oboe has a frequency profile as suggested by the Stensager experiment with air pressure constant.

4. The above are average profiles that suggest general characteristics of the average oboe. The data of this experiment and that of the Stensager experiment suggest that probably no two oboes have identical profiles. Nevertheless, the average profiles are useful in analyzing the profiles of any individual oboe. This information may be useful to performers, teachers, acousticians, and instrument-makers.

5. The relationships among mouth air pressure, intensity, and frequency require more study. These relationships are complex; for example, mouth air pressure is used for several purposes in playing a woodwind instrument:

a. The instrument has a basic air pressure requirement that the player must meet as shown in this study.

b. Air pressure may be used together with embouchure (lips in playing position) and vertical jaw motion to control frequency.

c. Air pressure may be used with embouchure to control the loudness or dynamic range of the instrument.

6. Other variables must be controlled for a fuller analysis of the above:

a. The role of the reed requires separate analysis; a wide variety of reeds were used in this study to minimize the effect of the reed as a factor.

b. The role of the embouchure should be studied; Stensager controlled the influence of embouchure by using a controllable artificial embouchure. In this experiment, four players were used to average out or minimize embouchure effect. Given the complexity of the embouchure, these controls are barely adequate.

c. A factor that seems to be important and requires further study is the part played by the glottis (the space between the vocal cords). The question has been considered in the playing of brass instruments by Farkas[11] and Carter.[12] The effect of the glottis on the oboe seems to be different from that reported for brasses in that it may be related to pressure rather than dynamics.

---

[11] Philip Farkas, *The Art of Brass Playing* (Bloomington, Indiana: Brass Publications, 1963).

[12] William Carter, "The Role of the Glottis in Brass Playing," *The Instrumentalist*, Vol. 21 (December 1966).

Teachers and performers of the oboe and other wind instruments might be able to use scientific techniques to define and correct playing problems. The player would then know that his instrument had an air pressure profile to which he must adjust, and that each note or set of notes had frequency requirements that were partly met by air pressure changes. If, for example, a given pressure would help to produce A^5 in tune, then there would be no reason why the player could not attack the note with the required air pressure. If E^4 and E^5 were too loud and B^5 was too soft in relation to other notes in a musical passage, then there would be no reason why the player could not equalize dynamics deliberately. This would require an ability to judge the amount of air pressure that the performer exerts while playing. This experiment suggests that this can be learned as easily as learning finger-touch pressure.

The intensity profiles of an instrument could serve the performer and the teacher as a guide to loudness level as suggested by Figure 8. The manufacturer and acoustician might also discover more about the relationship between the performer and his instrument that would be useful in the study, designs, and production of wind instruments.

Western Washington State College