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Physiological Differences Between the Trained and Untrained Speaking and Singing Voice

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Summary: This study concerns the premier singing voice and its relationship to physiological aptitude. Research literature is reviewed that indicates that during singing the trained singer uses different physiological strategies in comparison with the untrained singer, and that the noted physiological differences (respiratory, laryngeal, articulatory) occur during singing only and not during speech. Further, a study was conducted that compared the ability of trained singers versus untrained individuals to (a) discriminate differences in self-generated air pressures and (b) produce and maintain a constant level of air pressure. No significant differences were found between the trained and untrained groups in their ability to discriminate and/or control breath pressure. Combined results of previous studies and present findings lead to the tentative conclusion that the excelled singer is not physiologically endowed and/or "gifted," but rather has benefited from technical voice training. **Key Words:** Physiological aptitude—Trained singers—Untrained singers.

Three years ago at the Thirteenth Symposium on "Care of the Professional Voice" in New York City, Hollien (1) discussed what he called that "Golden Voice." He asked the question, "Is that golden voice—that premier singer—the product of the native talents and motivation of the artist or primarily of the modifications of the system accomplished by the efforts of the voice teacher?"

When asked, trained singers themselves have varied opinions as to the contribution of the teacher to the development of an excelled singing voice. Some maintain that it is a blend of the talent possessed by the performer and the guidance of the teacher. Others attribute most to the teacher, while there are some who attribute almost nothing to the teacher and nearly all to what might be considered physiological aptitude, or "God-given talent."

There are some physiological data available in the research literature that are beginning to shed light on this controversy. Presently, the evidence is overwhelming that during singing the trained singer uses different physiological strategies in comparison with the untrained singer (2–12). The evidence is equally convincing that the reported physiological differences occur during singing only, and not during the act of speaking (2,3,6,12), that is, during speaking, both trained and untrained singers use similar respiratory, laryngeal, and articulatory maneuvers or strategies.

With respect to respiratory behavior, Allen and Wilder (2), Formby et al. (4), and Watson and Hixon (12), utilizing patterns of chest wall dynamics or breath groups, have indicated that during the act of singing, trained singers employ different respiratory strategies as compared with untrained singers. However, those individuals with untrained voices make no distinction in respiratory adjustments between singing and speaking (13). When trained and untrained individuals are compared during speaking tasks, each uses similar respiratory behaviors (2,12).

Most of the research directed at assessing the

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differences in laryngeal behavior for trained versus untrained singers has been in association with laryngeal positioning. As reported by Brown et al. (3), Shipp and Izdebski (10), and Sundberg (11), the most consistent finding is that the untrained subject's usual behavior is to position his or her larynx upward as vocal frequency is raised and downward as vocal frequency is lowered; whereas for the trained singer, the larynx position is rarely above its physiologic rest position and is generally stabilized or lowered in association with increasing frequency. Sundberg associated this laryngeal lowering by the trained singer with a spectral peak of ~3,000 Hz, which has been related to the "singer's formant."

A variety of techniques have been incorporated to study the articulatory dynamics of singing, including measurements of intraoral breath pressure, lingual pressure, spectral waveforms, and oral-pharyngeal structural positioning and measurement patterns via cineradiography. Brown (14), Brown et al. (3), and McGlone (5,6) have reported data that generally agree that trained singers use different articulatory gestures for singing as compared to speaking. On the other hand, an individual with an untrained voice does not differentiate articulatory strategies for singing or speaking, and the trained singer uses articulatory maneuvers for speaking that are similar to those of untrained individuals—much as was the case for respiratory behavior.

The combined results of the above studies have provided evidence that trained singers, when compared with untrained individuals, use different physiological strategies for singing, but not for speaking. These findings suggest that the exceptional singer, rather than being physiologically endowed or "gifted," simply excels in developing appropriate strategies that enhance the tonal quality and other performance demands sought, which is facilitated through the teacher and/or the training method.

PURPOSE

One aspect of developing appropriate physiological strategies to help the trained singer to enhance vocal quality may be the development and refinement of a highly sensitized vocal tract. The data to be reported here will compare the oral sensory abilities of a group of trained singers with those of a group of individuals with no professional training in singing. The premise and protocol for establishing the oral sensory skills for normal speakers were modeled after Williams et al. (15). These data will contribute, in part, to the further question of whether or not the "gifted singer" may be physiologically predisposed or unique from the nonsinger. Specifically, the purpose of this study was to compare the ability of a group of trained and untrained singers to detect and monitor changes in intraoral breath pressure.

METHODS

Subjects

The subjects for this study included 10 women with professional voice training and 10 women with no voice training. The group of trained singers ranged in age from 18 to 44 years, with a mean age of 29 years. In addition, they exhibited a range of professional voice training from 2 to 30 years, with a mean of 8 years of experience. Further, they all had professional performance experience and all were pursuing professional careers in vocal music. The 10 subjects in the untrained group were matched for approximate age to the trained singing group. All subjects in both groups were required to fill out a questionnaire to determine that their speech and pulmonary functions were within normal limits and that they had no history of lip, face, or mouth trauma or temporomandibular joint disorders that had resulted in any apparent sensorimotor dysfunction.

Instrumentation

To estimate the oral sensory acuity of the subjects, they were asked (a) to discriminate differences in their self-generated intraoral air pressures in comparison with a set standard pressure of 5 cm H_2O (discrimination task) and (b) to produce and maintain a constant level of intraoral air pressure of 5 cm H_2O for a period of 5 s (steady-state task). This pressure level of 5 cm H_2O was chosen as it approximates a pressure typically produced by normal female speakers for a variety of consonant phonemes (16–19). The subjects were instructed to gently blow into the end of a polyethylene tube with an outside diameter of 5 mm and an inside diameter of 3 mm. The subjects positioned the end of the tube into the front of their mouths by ~5–7 mm, and then made closure around the tube with their lips. The other end of the tube was connected to a differential pressure transducer (Statham PM6TC), which then led into an IBM PC-XT. A software program was developed that allowed the examiner to preset the level of pressure that the subject was to attain when blowing into the tube. Pressure levels could be programmed as low as 0.01 cm H_2O and as high as 10 cm H_2O. The change between pressure settings could be programmed increments as low as 0.01 cm H_2O. A subject's oral air pressure was converted into voltage that was proportional to the air pressure applied (0.007 V/1 cm H_2O). A modified voltage meter provided subjects with visual feedback as to when their oral air pressure equaled the level preset by the examiner. The scale on the voltage meter was full scale from zero pressure to maximum pressure of 10 cm H_2O. When the subject blew into the tube with enough pressure to attain the preprogrammed level, the needle on the voltage meter would be vertically oriented to the center position.

To define the resolution and stability of the air pressure transducer and computer system, a controlled pressure of 5 cm H_2O was introduced through the same tube that the subjects blew into, and internal electrical variations to this pressure were measured continuously over a 40-s period. Over the 40 s there was a loss of only 0.24 cm H_2O. This loss of pressure was apparently due to small leaks around the several tube connections. As there was a small but constant loss of pressure over time, a regression analysis was computed to define the level of stability of the instrument at any moment in time to this pressure level. The standard error was calculated to be 0.0069 cm H_2O, revealing the existence of no significant noise within the system. Thus, any variation noted in the subject's attempt to maintain a sustained steady level of intraoral air pressure would be due to factors other than electronic noise within the system.

Intraoral air pressure discrimination tasks

The discrimination tasks were conducted under the conditions of an open tube and a closed tube system. For the open tube, a bleed valve was opened such that the subjects were required to continuously exhale to produce and maintain the required air pressure. This task approximated producing continuants, or fricative sounds—/s/ and /z/, for example. While an air flow rate of ~450–500 cm^3/s has been found to accompany productions of the fricative /s/ (20), experimentation prior to the actual collection of data indicated that a simulated air flow rate of ~450 cm^3/s proved to be too taxing for a pilot subject. Therefore, to inhibit subject fatigue, the air flow rate was reduced to 109 cm^3/s. The closed tube task required the subjects to blow with a specified intraoral air pressure without having to exhale. This simulated in part the production of stops such as plosive sounds—/p/ and /b/, for example.

For the discrimination tasks, a modified method of constant stimuli was used (21). Each subject was presented with a series of paired pressure settings, one at a time. The first pressure setting of each pair was the standard, or reference, value of 5 cm H_2O, and the second was a comparator value of a preselected different amount. Standardized procedures required each subject to blow into the tube with sufficient force to center the indicator needle to zero on the voltage meter, where zero equaled 5 cm H_2O. The subject would visually monitor the voltage meter while blowing into the tube. The subject was instructed to use the first oral air pressure of each pair as the standard or reference force. The subject was then instructed to momentarily release all breath pressure in the tube. Immediately, the experimenter increased the pressure setting by an increment of 0.2 cm H_2O relative to the previously presented comparator setting. The subject was required again to blow into the tube with enough pressure to recenter the needle on the voltage meter to zero. The subject was then asked to report whether the second pressure level in the pair required more, less, or an equal amount of oral air pressure compared with the standard pressure setting.

This procedure of paired comparisons was continued until a difference limen (DL) value could be established for each subject. DL was defined as the level of air pressure beyond the standard air pressure value at which the subject gave the first of three consecutive correct responses. Two ascending trials were conducted for each subject for both the open and the closed tube tasks, and the mean of the two used as the measured.

Intraoral air pressure steady-state tasks

For the steady-state tasks, the subjects were again required to blow into the tube with enough pressure to bring the needle to the zero reading on the voltage meter. The pressure required for this task was 5 cm H_2O. Subjects were instructed to hold the pressure as steady as they could for at least 5 s. Subjects were instructed to maintain an open airway without occluding the open end of the

TABLE 1. *DL scores (cm H_2O) and means associated with the pressure discrimination tasks for the untrained versus trained subjects for the open tube (OT) and closed tube (CT) conditions*

Untrained subject no.	DL score (OT)	DL score (CT)	Trained subject no.	DL score (OT)	DL score (CT)
1	0.7	1.9	1	0.6	1.1
2	1.0	1.0	2	1.4	1.8
3	1.0	1.1	3	0.6	1.4
4	0.4	1.1	4	0.7	1.6
5	0.3	0.6	5	1.0	1.9
6	0.6	0.6	6	0.7	1.1
7	2.5	0.6	7	0.7	0.9
8	1.0	1.5	8	1.0	0.6
9	1.3	1.5	9	0.2	0.8
10	1.2	1.5	10	0.8	0.5
Mean score	1.00	1.14		0.77	1.17

tube with their tongue. They were required to do this task four times: twice for the open tube condition where, on one occasion, they were given visual aid via the meter reading throughout the 5-s hold period, on a second occasion, they had no visual feedback, and after the subjects brought the oral pressure to 5 cm H_2O, the meter was turned off throughout the 5-s period; and twice for the closed tube condition, once visually and once nonvisually.

RESULTS

The results of the discrimination tasks can be viewed in Table 1. The DL scores associated with the open and closed tube conditions were similar both across groups and across conditions. Indeed, as can be seen in Table 1, the mean DL scores for the singers and nonsingers, for the open and closed tube conditions, approximated 1 cm H_20. Standard analysis of variance procedures (22) applied to the data indicated that the DL scores were not significantly different ($F = 0.408$; $df = 1{,}38$; $p = 0.5266$) between the untrained and trained subjects, nor were they significantly different when comparing the open versus closed tube conditions for the trained ($F = 4.703$; $df = 1.18$; $p = 0.0438$) and untrained ($F = 0.330$; $df = 1.18$; $p = 0.5727$) singers at the 0.01 level of confidence.

For the steady-state conditions, a variance score was calculated for each subject for each of the four experimental conditions. Figure 1 is an illustration of the printout as compiled by the computer of a trained subject's attempts to hold her oral air pressure constant at the zero meter reading, where zero represented 5 cm H_2O, as shown. This example is for the open tube visual condition. Figure 2 is an example of a nonvisual condition, where considerably more variation around the zero meter reading is evident. The computer sampled the varying oral pressure every tenth of a second. Thus, for the 5-s period during which the subject attempted to maintain a constant oral pressure at 5 cm H_2O, a total of 50 samples were observed, from which a variance score was calculated for each subject at each condition. Table 2 represents the obtained variance scores for each subject's attempts, for each condition, where the variance score is based on the variance around a zero meter reading. Focusing on the

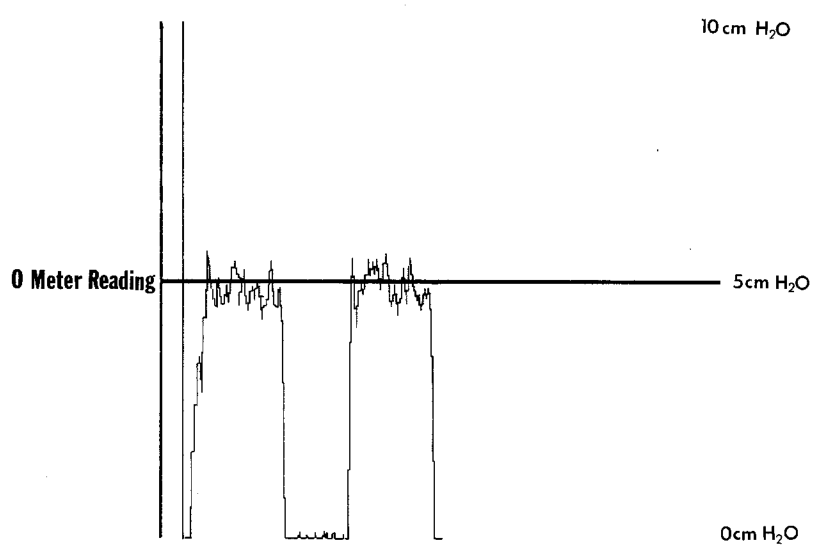

FIG. 1. Illustration of actual traces of a trained subject's two attempts to hold air pressure constant at 5 cm H_2O (zero meter reading) for the open tube visual condition. Each attempt represents a time period of 5 s.

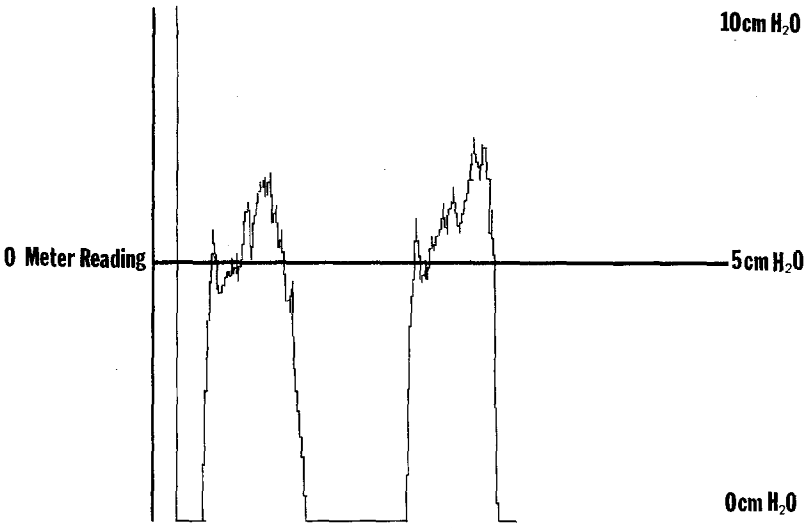

FIG. 2. Illustration of actual traces of a trained subject's attempt to hold air pressure constant at 5 cm H_2O (zero meter reading) for the open tube nonvisual condition. Each attempt represents a time period of 5 s.

overall variance scores, it can be seen that no apparent trends are evident when comparing the untrained with the trained subjects. Figure 3 is a graphic representation of the group distribution of variance scores for each of the untrained subjects across the four conditions. It is best illustrated in this figure that, for the majority of the subjects, the variance was uniformly distributed. Only two or three of the subjects markedly departed from the central tendency of the group variance, and for only one condition in each case. Figure 4 is an illustration for the trained group. Here again, only two or three of the subjects varied markedly from the overall group distribution of variances, and again for only one of the conditions in each case. An analysis of variance procedure (22) applied to these data indicated no significant differences between the obtained variance scores for the untrained versus trained group ($F = 0.452$; $df = 1.38$; $p = 0.5035$) at the 0.01 level of confidence. There were, within both groups, differences between the visual versus nonvisual conditions ($F = 5.224$; $df = 3.76$; $p < 0.0025$). As was expected, subjects were generally more variable during the nonvisual conditions.

DISCUSSION AND CONCLUSIONS

The combined results of this study would indicate that trained singers have no better oral sensory perceptual skills in controlling and/or monitoring intraoral breath pressure than individuals of the same age who have had no voice training. Thus, the hypothesis that excelled singers may exhibit a more sensitive sensory receptor system in comparison with untrained persons is not supported by this study. Moreover, these results, combined with previous findings indicating that trained and untrained

TABLE 2. *Individual and overall variances (S^2) associated with the four steady-state conditions, open tube visual (OTV), open tube nonvisual (OTNV), closed tube visual (CTV), and closed tube nonvisual (CTNV), attempted at the selected pressure target of 5 cm H_2O for the untrained versus trained subjects*

	Condition			
Subject no.	OTV	OTNV	CTV	CTNV
Untrained				
1	0.09	0.27	0.01	0.42
2	0.11	0.04	0.00	0.32
3	0.05	0.11	0.28	0.11
4	0.05	0.10	0.04	0.22
5	0.14	0.29	0.01	0.81
6	0.18	0.29	0.04	0.08
7	2.61	0.53	0.08	0.33
8	0.52	1.55	0.02	0.09
9	0.06	0.05	0.16	0.47
10	0.10	0.15	0.01	0.10
Overall S^2	0.46	0.81	0.08	1.50
Trained				
1	0.19	0.04	0.08	0.12
2	0.08	3.61	0.04	0.10
3	0.24	0.10	1.62	0.29
4	0.20	0.67	0.11	0.18
5	0.11	0.28	0.14	0.40
6	0.18	1.15	0.39	0.43
7	0.06	0.24	0.05	0.01
8	0.03	0.37	0.03	0.57
9	0.50	0.38	0.02	0.36
10	0.03	0.02	0.06	0.02
Overall S_2	0.22	1.29	0.31	1.55

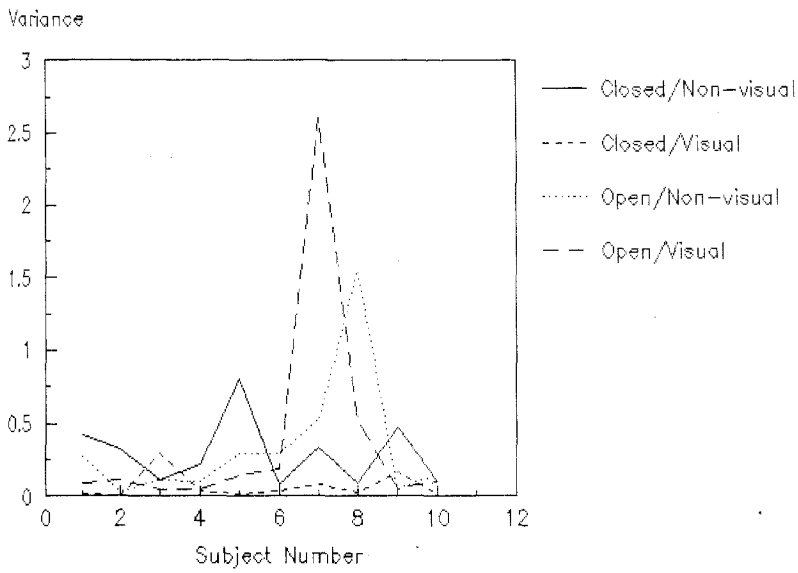

FIG. 3. Graphic representation of the variances of the trained singers for each of four experimental conditions.

singers use similar physiological strategies for speech and differ only during the singing process, also cast doubt on the premise that the excelled singer is physiologically endowed, or "gifted." Indeed, as yet, there are few or no experimental data that indicate that the excelled singer is physiologically "gifted."

What, then, contributes most to the development of that "Golden Voice," referred to by Hollien (1)? Is it physiological aptitude, self-motivation, the teacher, or the teaching method? It is our opinion, based upon the available evidence, that a combination of personal motivation, the teacher, and the training method is primary to the eventual development of a premier singing voice. Of course, we cannot totally rule out that there may be other physiological or even structural differences that enhance the singer's ability. As yet, any technology that may exist to evaluate structural and/or tissue differences has not been used with this subject population. Nor can we rule out that the excelled singer may be neurologically superior in terms of auditory reception, perception, and refinement of musical tones, which are translated into physiological control of the speech mechanism, as this was not tested in this study. It does appear, however,

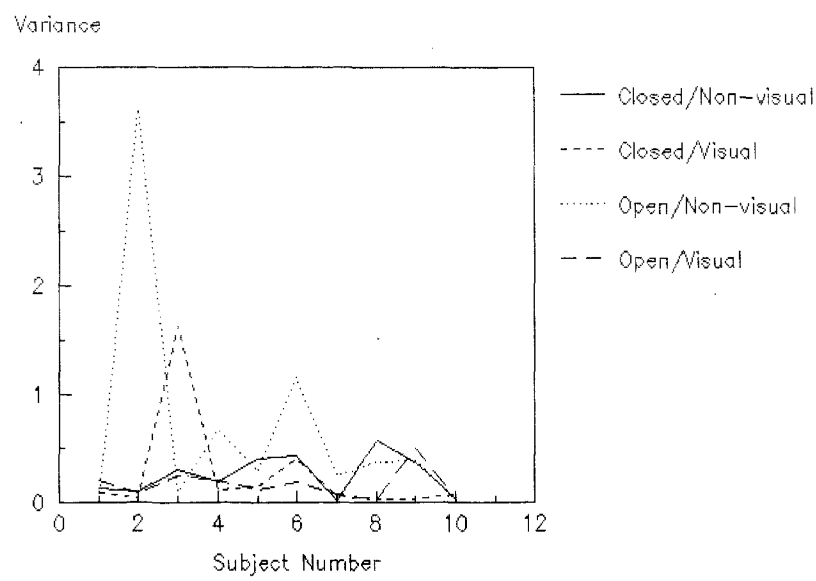

FIG. 4. Graphic representation of the variances of the untrained subjects for each of four experimental conditions.

that the trained singer understands the appropriate use and adjustments of the respiratory, laryngeal, and articulatory systems to achieve a desirable quality and repertoire of golden tones.

In conclusion, the pertinent research literature and the results of the present study on oral-perceptual sensory skills have led the authors to the opinion that the excelled singer may not, necessarily, be physiologically (respiratory, laryngeal, articulatory) endowed, but rather has benefited from the technical training of the voice. Before this tentative conclusion can be totally accepted, or rejected, further research is necessary, especially as related to the structural (anatomical), tissue, and auditory processing differences that may exist between the excelled singer and the untrained voice.

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DISCUSSION

Scherer: With respect to training of singers, it seems to be apparent that greater sensitivities are created so that control mechanisms are more precise. Would you like to speculate with respect to your results or what you might think is happening subglottally or glottally, with respect to mechanoreceptors and training for sensitivities?

Brown: Are you saying that there is heightened sensitivity in the singer, or we suspect that there is?

Scherer: Would you suspect that trained actors and singers have heightened sensitivities and control?

Brown: I would say that there doesn't appear to be any evidence that the singer is gifted in the sense that God gave him a structure which was unique. That may be true, but we haven't found that at this time. Thus, obviously, they have learned to use this mechanism. They have learned to make the appropriate respiratory, laryngeal, and articulatory maneuvers, where these different types of movements are necessary. One of the things that I suspected was they may be more aware. That is, they are even better at sensing the difference, the imagery. They turn that imagery into sensations that end in the resultant desired quality. I only tapped one aspect of it, the oral pressure sensing unit, not during a singing exercise, but just comparing the ability in any procedure, which has its good points and bad points. The procedure would assess whether a professional singer could sense the pressure: To hold it, to bring it to a point, feeling the pressure. We found that they were no better at doing that than were the untrained subjects. Consequently, I would certainly have to go back to the fact that given all I know about the physiology of the singer, it seems there is a more important aspect of training, that is to develop the imagery necessary to make the appropriate physiological gestures that go along with the quality, or gifted, or golden voice.

Scherer: I would like to ask the audience: For those who teach voice training, speaking or singing, what do you think are the elements that are heightened in sensitivity or training? This might help to enliven some of our scientists.

Howell: One of the most important things for all us who are in the profession is the concept of how we really respond to vocal models that we hear. How we respond to our own idea of what is beautiful singing or lousy singing, or beautiful speech. As far as I am concerned, to teach efficient singing and to teach efficient speech is the same thing. The most important thing is concept. After that, we do all the breathing exercises all of us know about, becoming aware of the physiology of the throat and the acoustical space, so that we can use it to produce the most beautiful and functional sounds our bodies can make. It starts with concept.

Hixon: I'm really surprised at the audience response to endowment versus training is not as violent as I thought it would be. I'd like to ask Sam, do you think that the singer is gifted with a special central nervous system? If I looked at world class painters I couldn't look directly at them in any structures and predict what the product would be. Why would I think it would not be the same with singers?

Brown: Why would you think they were physiologically endowed?

Hixon: Are they endowed with better central nervous systems that can do things, like take auditory information and convert it into production like a painter can take visual and convert it into performance?

Brown: This particular question, has been directed at the golden voice supporter. They talk about auditory feedback and we didn't tap that. It certainly may be that in the premier singer, or the trained performer, but we haven't looked at everything that might very well be a product of God-given talent. Given all the data on physiological production that I have so far, I would say that the gifted singer is no different in the structural mechanism in terms of that behavior.

Hixon: Do you think the first gifted singer came before the first gifted teacher?

Brown: Did I ever ask you the question about the chicken and the egg? That's not fair! Your point's well taken, though.

Titze: A point was made earlier about symmetry in the larynx. It's my feeling, although very little study has been done, that that could be an area where gift might play a role. Under high levels of physiological tension produced, when creating high pitches for example, any amount of asymmetry in the structure would tend to throw the system into asymmetric kinds of vibrations in different modes. It's just a hunch of mine that a well grown symmetric larynx would go a long ways toward making a high quality instrument. If we could only get all the larynxes from the great singers and put them side by side and look at them . . .

Audience: Often you see professional singers with asymmetrical larynges. When you look at them, they look very asymmetrical. I think Brodnitz has written in one of his books about one very talented singer who had one vocal cord that didn't move at all. Both vibrated, of course, but it was very asymmetrical.

Titze: It just doesn't make any theoretical sense. Maybe they're compensating for something else, or maybe they have put stresses on there. It just doesn't make any sense that an asymmetric larynx would vibrate better than a symmetric one.

Audience: I didn't say that it vibrated better. It vibrated equally well.

Scherer: The issue may not be so much the motion of the vocal folds but the product of the respiratory system, the vocal folds, and the acoustic system. That is, the air flow exiting the larynx. If the air flow exiting the larynx is fairly periodic and of the right shape, no matter how it was obtained, you might have the potential for a fine voice.

Sataloff: Many of those apparent asymmetries, large structural asymmetries, that we see under continuous light, occur in larynges which appear symmetrical under stroboscopic light. In fact, it doesn't really matter if one vocal fold appears grossly thicker than the other, or even to some degree if one abducts or adducts more quickly than the other, so long as when they are in phonating position the cover layer functions in a symmetrical fashion. In fact, if there is asymmetry of vibratory function, then you have a disordered voice.

Scherer: So the moral there is if you have funny looking larynx, it might still be all right if the lamina propria vibrates correctly.

Titze: Here's where this compensation may come in. If, in fact, you have an asymmetry in the mucosal layer, you may do something gross in the structure to compensate and make it more symmetric where it counts. Hence, you may observe something which looks funny, but in the actual function it is rather symmetrical.

Audience: When you talk about a gifted singer, are we talking about somebody whose equipment can stand the pressure of Tina Turner's screaming for 25 years or are we talking about the endurance of a Lily Pons who sings until she's 81? What's the definition?

Brown: I took Hollien's term, actually. As a researcher, I do have to define my population. In my population I was looking at singers who were trained performers, had professional training, primarily university type training, had performed professionally, were in training institutions to perform professionally, and had the potential to be successful singers. That is, their peers and their teachers deemed that they had that potential. That's what I refer to when I refer to a gifted singer. I've talked about the individual that indeed had been given such status. I'm not going to define gifted other than that.

Hixon: We've been arguing about this for 15 years: what's a trained and an untrained singer. The best definition I come up with my students is the gifted singer is the one who can evoke ticket buying behavior in the audience.

Titze: I want to make one more point about gifted. I think there's a gift for endurance that I think certain people have and other people don't have. If we compare ourselves with the sports world, they're the Bill Walton type of basketball players who seem to have all the physical stature and the innate ability, but because of some weak knees or ankles or something, lack the ability to endure. And there's other players that are out there until they're grandfathers still playing. That doesn't have a whole lot to do with technique at that point, it may have something to do with some of the biomechanical limitations that you have in your particular system. The person who has the gift to endure obviously has the gift to practice longer and to use all the skills that he had been taught. Whereas the one that has to quit after 20 minutes will always have that handicap.

Scherer: What are the elements of endurance?

Dobelle: I think we've been handed down a tradition of what is beautiful in singing. That's what we go by. At different periods of time there were different concepts of beautiful singing. At the present time, I think it means the classical singer who can go through a concert, an opera singer. I hope just because the rock singers have sold so many tickets 50 years from now when we have a symposium we don't say "That was a gifted singer because he sold tickets." I hope the rock singers will not be the future concept of beautiful singing.

Sataloff: I suspect that other opinions will be heard about our tendencies to impose our own aesthetic judgments of what constitutes beautiful singing on the people with whom we work. Although I agree with your opinions to some degree, it's a dangerous tendency for us, certainly as physicians, but also as scientists and teachers. There are more legitimate definitions of beauty than solely those from us who sing opera.