THE VIBRATO[1]

By Jacob Kwalwasser

Method of photographing and measuring; the parallel vibrato; the opposite relationship vibrato; the pitch vibrato; the intensity vibrato; changes from one type of vibrato to another; tones which have no vibrato; effect of voice placement on the vibrato; effect of vowel quality on the vibrato; effect of voice registers, etc.; effect of intensity changes, etc.; effect of voluntary interference, etc.; influence of age, sex, and training, etc.; the vibrato defined; current literature on the vibrato; summary; bibliography.

This study was undertaken for the purpose of gathering more data on the nature of the vibrato. Such factors as training, sex, age, voice placement and vowel quality were investigated in an effort to ascertain their influence on the pitch, time and intensity fluctuation of the vibrato.[1]

Method of Photographing and Measuring

The photographic method was used exclusively in this study. A strip of super-speed moving picture film was fastened to the drum of the tonoscope (15) which is equipped with a synchronous motor to insure regularity in the rate of revolution. A Dorsey phonelescope, mounted on the tonoscope, was used as an optical lever. The observers sang directly into the mouthpiece of the phonelescope. Each photographic record represents a tone sustained from .50 sec. to .75 sec.

The method employed for measuring pitch in terms of wave-lengths was developed and described by *Simon* (15). It consists in measuring wave-lengths either individually or in groups with the aid of a vernier microscope. The constant, 2,425 millimeters, the rate of speed per second at which the film passes the point of exposure, divided by the wave-lengths, yields the vibration rate

[1] Grateful acknowledgment is hereby made to Dean Carl E. Seashore, who directed this study. I wish to express my appreciation, also, to faculty and students of the Music School and Model School, who contributed the tones which constitute the subject matter of this thesis.

per second. As demonstrated by *Simon* (15) the pitch and time method of recording have a high order of reliability—finer than demanded for the present purpose.

The intensity readings are less valid than the pitch and time readings. There is first the danger of one or more resonance regions in the phonelescope. The "own" resonance is at 551 d.v. This frequency was therefore avoided in all our tones of the present study. A phono-photograph of the region from 121 d.v. to 400 d.v. reveals no marked period of resonance anywhere in this scale. At the frequency of 275 d.v. which is the sub-octave of the free period, very slight change is found in the amplitude of vibration. Such factors as the length of the optical lever, distance of the singer from the membrane, influence of the tube leading to the membrane, etc., were subjected to little or no experimentation. The following use of the amplitude of the wave as a distinct measure of intensity is therefore intended as merely a rough indication of quantity for which the procedure is perhaps qualitatively adequate.

The Parallel Vibrato

The vibrato is an observable periodicity of pitch or intensity pulsations or both, falling normally within a more or less regular rate of occurrence varying from four to nine per second. The parallel vibrato is one in which the pitch and intensity pulsations are periodic, parallel, and synchronous; *i.e.*, a general tendency for the crests and troughs of pitch and intensity to be more or less coincident in time, extent, and duration.

Table I shows the pitch, intensity, and time measurements of 63 tones of this type. In order to facilitate the discussion of these tones, each column will be taken up separately. Pitches to be reproduced were sounded by means of tuning forks. The observers were instructed to sing the pitch they heard, using a specific vowel or voice placement. In a few cases no standard pitches were given, but generally the pitch used was of a frequency of 220 d.v. Standard pitches are listed under S.P. in Table I. The columns labeled M. show the means in time, pitch,

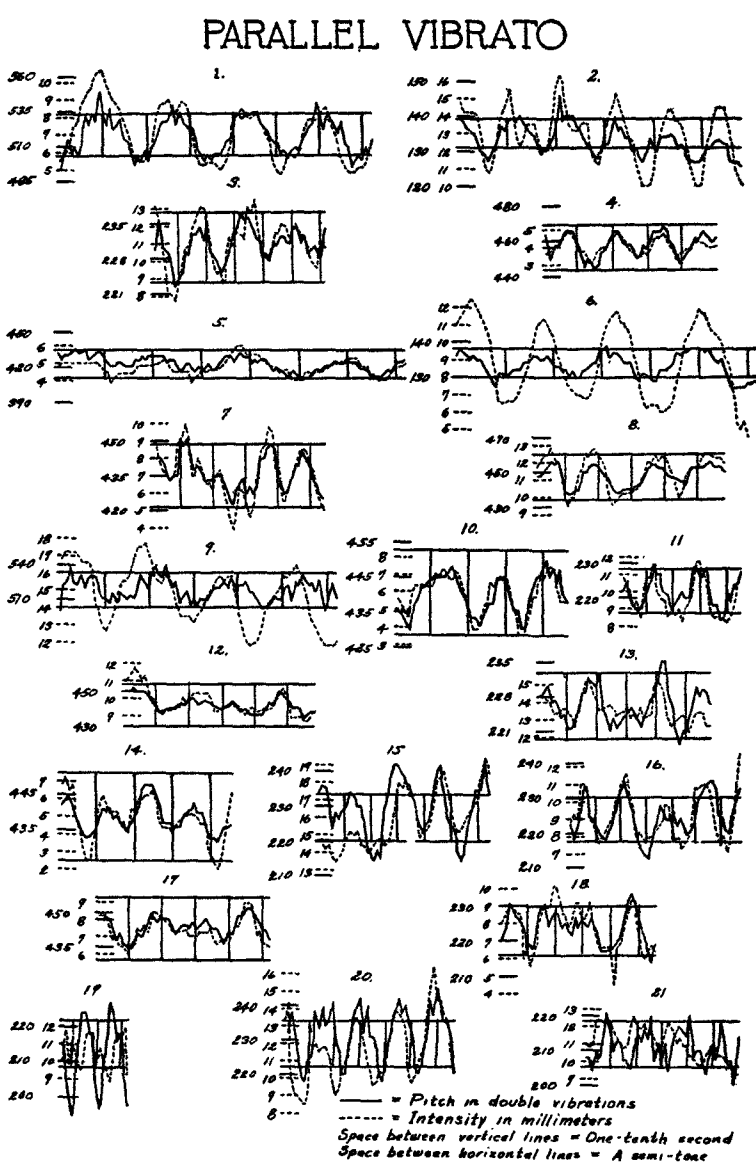

PARALLEL VIBRATO
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18.
19
20.
21
= Pitch in double vibrations
= Intensity in millimeters
Space between vertical lines = One-tenth second
Space between horizontal lines = A semi-tone

Fig. 1

and intensity, respectively. These columns give the true means, in each case, computed from a series of time, pitch, and intensity readings. The column labeled E.D. gives the extent, *i.e.*, the amplitude of pitch deviations, for each tone in terms of per cent of a tone. E.D. is simply twice the average deviation converted into per cent of a tone. Columns marked A.D. represent measurements of average deviations in intensity and time, while those labeled M.D. represent maximum deviations.

The unit of measurement for the intensity mean is millimeters, but the average and maximum deviations are in terms of per cent of the mean. The unit of measurement for time is in hundredths of a second. The average deviation is in terms of per cent of the mean, also.

The average extent of pitch deviations for the 63 tones of Table I is 23 per cent of a tone; the maximum pitch deviations average 59 per cent of a tone. The mean and maximum intensity deviations are 11 and 50 per cent of the mean respectively. The average duration of pulsation is .16 sec., with an average deviation of 9 per cent.

Fig. 1 contains a graphic representation of 21 tones of this class. In addition to the key to these graphs given in the cut, note that pitch is denoted by d.v. (at the left) and followed by degrees of intensity denoted arbitrarily in terms of millimeters of amplitude. This measurement of amplitude of intensity or vertical displacement of the sound wave was taken directly from the original photograph. The numbers on the graphs correspond to the numbers found in the first columns of the tables.

TABLE I. *Parallel vibrato*

		Pitch			Intensity			Time	
No.	S.P.	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
6		134	.27	.69	9	.21	.89	.16	.05
89		267	.25	.66	18	.07	.29	.17	.07
92		273	.26	.78	22	.10	.44	.14	.08
2		135	.57	1.30	13	.09	.43	.11	.07
104		527	.26	1.33	7	.45	1.99	.15	.15
5		424	.20	.44	5	.07	.38	.18	.12
110		465	.18	.53	28	.12	.58	.15	.15
113		333	.19	.63	14	.08	.31	.15	.20
115		551	.21	.55	10	.20	.94	.14	.25
122	256	257	.22	.33	5	.22	1.00	.15	.05

TABLE I—(Continued)

			Ptich		Intensity			Time	
No.	S.P.	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
124	256	267	.15	.43	15	.08	.44	.19	.04
1	512	519	.39	1.03	7	.07	.82	.16	.05
9	512	518	.23	.60	15	.10	.36	.16	.05
128		462	.58	1.23	8	.20	.95	.16	.05
129	512	516	.40	1.12	7	.29	1.15	.17	.09
130	512	532	.29	.68	14	.13	.50	.16	.05
131	512	525	.34	.88	9	.27	.88	.15	.05
133		541	.19	.35	7	.13	.54	.17	.04
134		532	.43	.84	6	.26	1.01	.15	.01
150	440	443	.19	.54	7	.16	.63	.14	.00
7	440	435	.13	.44	7	.17	.70	.13	.11
14	440	439	.20	.52	5	.20	1.00	.14	.05
10	440	441	.30	.62	6	.17	.68	.14	.10
155	440	445	.28	.62	6	.12	.63	.15	.00
156	440	444	.11	.18	6	.04	.21	.14	.00
157	440	448	.15	.36	6	.05	.32	.15	.06
158	440	448	.26	.72	3	.08	.52	.15	.06
159	440	441	.21	.36	6	.05	.30	.16	.10
17	440	442	.14	.36	7	.08	.41	.16	.05
8	440	448	.15	.26	11	.07	.29	.16	.09
4	440	457	.23	.43	4	.07	.41	.14	.09
165	440	449	.11	.36	15	.09	.37	.14	.10
12	440	443	.11	.26	10	.07	.32	.16	.05
171	220	219	.22	.52	8	.04	.19	.15	.06
19	220	215	.44	.76	11	.08	.30	.11	.00
21	220	215	.22	.52	11	.07	.32	.15	.12
179	220	220	.17	.44	8	.05	.20	.15	.06
180	220	226	.16	.44	10	.05	.19	.16	.14
181	220	223	.18	.44	18	.05	.25	.15	.09
182	220	224	.13	.44	16	.05	.23	.12	.14
183	320	329	.35	1.39	11	.09	.53	.16	.04
184	128	135	.10	.44	22	.10	.47	.17	.16
192	220	220	.16	.36	12	.04	.24	.14	.10
194	220	220	.18	.60	17	.04	.19	.16	.09
195	220	219	.18	.44	14	.04	.18	.19	.07
196	220	221	.16	.44	14	.03	.18	.22	.13
197	220	219	.17	.44	19	.05	.24	.15	.00
198	220	223	.13	.36	9	.04	.18	.15	.10
11	220	222	.19	.44	10	.09	.39	.15	.18
201	220	221	.26	.52	13	.05	.20	.18	.08
205	220	221	.21	.44	6	.05	.19	.16	.12
13	220	226	.23	.59	14	.04	.22	.22	.09
210	220	226	.20	.59	16	.05	.21	.19	.05
15	220	227	.34	.74	16	.09	.39	.12	.36
20	220	229	.34	.78	12	.12	.64	.14	.07
217	220	225	.19	.52	8	.07	.36	.14	.10
16	220	224	.28	.67	9	.11	.70	.16	.16
3	220	230	.22	.59	11	.10	.49	.18	.08
18	220	223	.27	.52	8	.08	.72	.16	.11
233	220	216	.38	.76	6	.19	1.05	.14	.05
239	220	218	.20	.44	8	.07	.39	.14	.07
121	256	259	.18	.43	6	.06	.36	.19	.04
			.23	.59		.11	.50	.16	.09

For legend see text.

The Opposite Relationship Vibrato

Twenty-four tones, representing 12 per cent of all tones possessing the vibrato, are found in Table II. In this type, the pitch crest is accompanied by an intensity trough, and the pitch trough by an intensity crest. (See Fig. 2.) While the direction of the two factors is opposite, both pitch and intensity are more or less coincident in time, extent, and duration.

The opposite vibrato is similar to the parallel vibrato, as is shown in the following figures.

	Pitch		Intensity		Time	
	E.D.	M.D.	A.D.	M.D.	M.	A.D.
Parallel vibrato	.23	.59	.11	.50	.16	.09
Opposite vibrato	.25	.63	.11	.46	.15	.06

The only significant difference is in the relationship of pitch and intensity.

TABLE II. *Opposite vibrato*

			Pitch		Intensity			Time	
No.	S.P.	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
200		160	.22	.53	7	.25	.79	.20	.03
42		155	.59	1.82	16	.14	.57	.18	.16
88	320	313	.22	.80	28	.09	.33	.17	.02
43	512	528	.31	1.05	6	.16	.73	.17	.02
106		417	.22	.44	14	.13	.43	.20	.07
44	512	525	.64	.97	9	.33	1.13	.11	.07
142		187	.16	.43	4	.12	.41	.14	.15
162	880	896	.18	.54	8	.05	.27	.14	.08
174	220	219	.19	.62	11	.05	.25	.14	.08
178	220	218	.15	.36	9	.04	.18	.15	.03
185	220	222	.17	.44	18	.09	.40	.16	.03
186	220	212	.20	.52	8	.03	.16	.16	.06
191	220	220	.17	.44	10	.04	.20	.15	.18
203	110	108	.14	.46	7	.06	.27	.14	.07
204	220	222	.10	.36	11	.10	.50	.13	.04
216	220	221	.17	.40	9	.08	.33	.13	.07
220	220	219	.20	.52	8	.04	.18	.15	.11
223	110	113	.13	.36	8	.05	.27	.13	.00
40	220	218	.17	.36	7	.09	.59	.15	.07
232	220	219	.11	.28	7	.05	.31	.15	.08
39	220	222	.38	.64	8	.19	.68	.14	.07
235	220	217	.60	1.56	6	.19	.71	.15	.05
38		329	.26	.61	6	.14	.73	.15	.03
41	220	219	.25	.72	6	.12	.64	.14	.08
			.25	.63		.11	.46	.15	.06

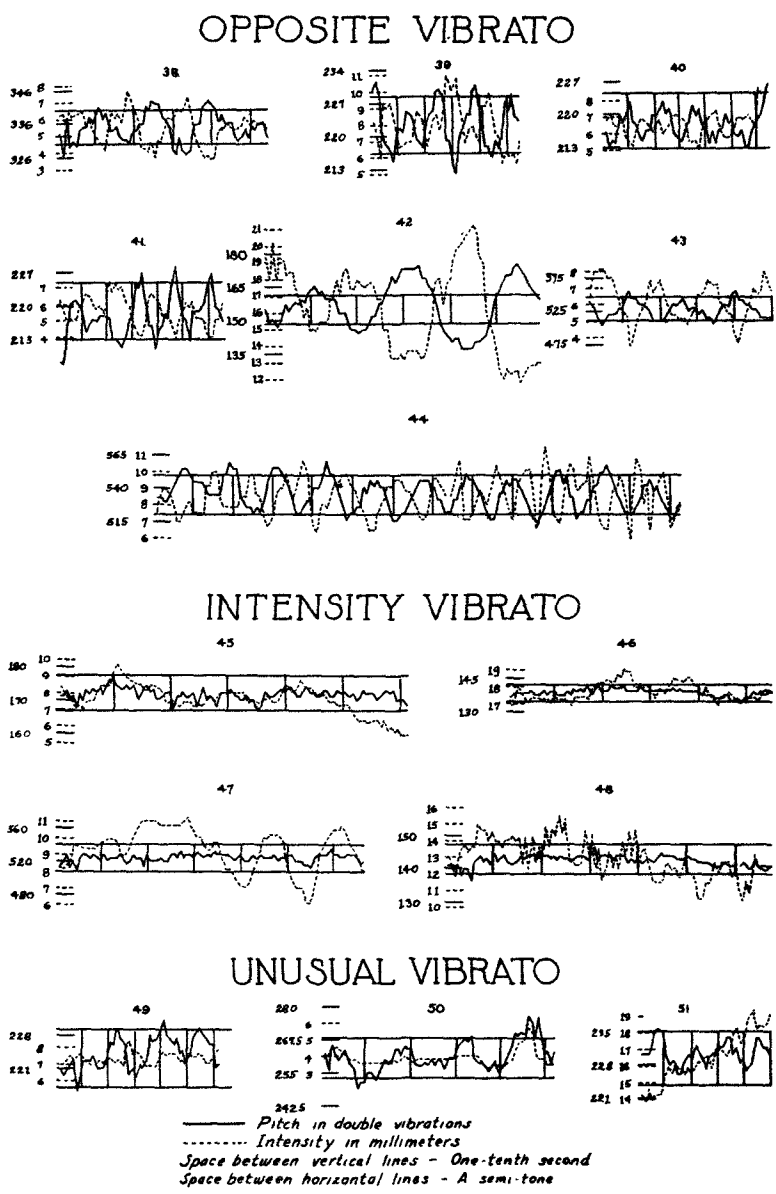

OPPOSITE VIBRATO
38
39
40
41
42
43
44
INTENSITY VIBRATO
45
46
47
48
UNUSUAL VIBRATO
49
50
51
Pitch in double vibrations
Intensity in millimeters
Space between vertical lines - One-tenth second
Space between horizontal lines - A semi-tone

Fig. 2

The Pitch Vibrato

In this vibrato the pitch factor alone reveals the periodicity. The intensity factor, which has been in either the same or opposite phase in former types, is now devoid of any cyclic characteristics, although it does fluctuate irregularly. This type of vibrato is by no means rare. Nineteen, representing 16 per cent of the total number of tones, were found in this study.

The pitch fluctuations for this class are somewhat smaller than those presented before, being E.D., 19 per cent, and M.D., 48 per cent of a tone. The intensity fluctuations are smaller than those found for any of the preceding types. In respect to rate, the pitch vibrato resembles the parallel vibrato.

TABLE III. *Pitch vibrato*

			Pitch		Intensity			Time	
No.	S.P.	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
36	256	251	.18	.43	5	.03	.15	.16	.09
137	220	219	.12	.44	5	.04	.15	.16	.11
30	220	213	.12	.32	18	.04	.06	.15	.03
37	220	211	.16	.44	4	.06	.31	.18	.03
35	440	449	.21	.54	4	.04	.13	.15	.01
170	220	219	.22	.52	8	.04	.19	.14	.07
34	220	220	.22	.52	10	.01	.06	.15	.04
173	220	217	.18	.36	8	.02	.26	.15	.08
175	220	216	.30	.76	8	.07	.29	.13	.05
190	220	221	.22	.60	9	.02	.16	.16	.23
193	220	220	.19	.52	13	.16	.72	.25	.06
208	110	110	.18	.31	6	.03	.17	.14	.20
33	220	224	.13	.33	9	.06	.39	.16	.06
214	220	221	.18	.41	8	.05	.30	.15	.06
219	220	223	.21	.52	6	.03	.16	.16	.11
221	220	221	.17	.52	14	.04	.19	.18	.12
225	220	221	.21	.44	6	.02	.14	.18	.08
31	110	112	.28	.64	5	.04	.23	.13	.08
			.19	.48		.04	.22	.16	.08

The Intensity Vibrato

In this type of vibrato the intensity factor alone reveals cyclic characteristics. Consult Table IV for measurements of the intensity vibrato and Fig. 2 for the graphs.

TABLE IV. *Intensity vibrato*

		Pitch			Intensity			Time	
No.	S.P.	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
45		172	.15	.45	8	.07	.51	.16	.28
46		137	.35	1.13	18	.02	.11	.14	.03
253		144	.13	.44	6	.05	.32	.20	.03
48		143	.13	.44	13	.07	.33	.10	.22
47		525	.10	.43	8	.17	.63	.19	.28
112		547	.11	.55	20	.04	.18	.17	.07
			.16	.57		.07	.35	.16	.15

Changes from One Type of Vibrato to Another

In order to facilitate the discussion of the vibrato, it has been arbitrarily divided into types or classes. An examination of Fig. 1, parallel vibrato, will reveal some cases that are parallel in regard to pitch and intensity, but are slightly out of phase. In tone No. 20 the intensity curve is " skewed " a little to the left of the pitch curve, while in the preceding tone the intensity curve is " skewed " a little to the right. No. 21 is a border-line case, for the phase relationship is almost 180 degrees. If the intensity curve were advanced a little in time, this tone would belong to the opposite vibrato type.

The last three tones of Fig. 2 are classified as unusual types of vibrato, since they change their pitch and intensity relationships from one type to another. No. 49 changes from opposite to parallel; No. 50 begins with no vibrato and ends parallel; while No. 51 resembles No. 49.

Tones Which Have No Vibrato

In a total of 147 tones included in this study, 28 are classified as belonging to the no-vibrato group. Untrained adults contributed 87 per cent of all their tones, and children 41 per cent of all their tones to this class. Only 7 per cent of the tones of trained singers were of the no-vibrato type. Table V gives the measurements of these tones, and Fig. 3 contains the graphs.

The pitch fluctuations may be as large as those found in tones containing the vibrato. But mere fluctuations do not necessarily result in the vibrato. The fluctuations must be progressive and

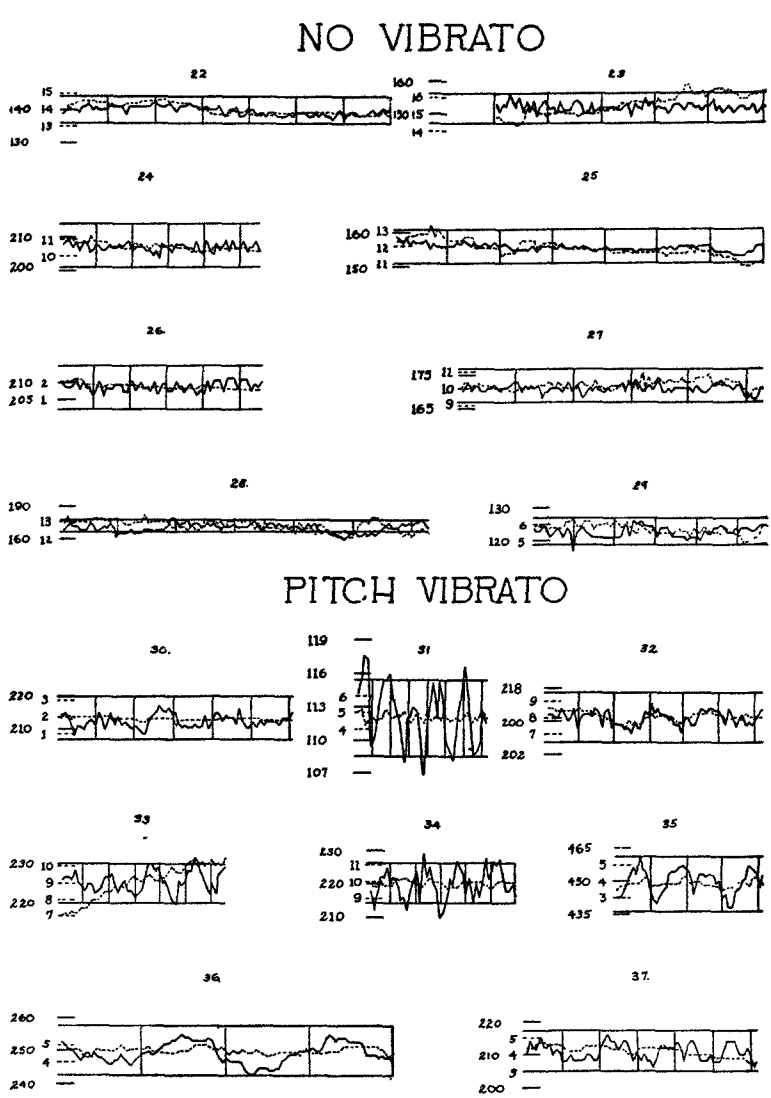

NO VIBRATO
22
23
24
25
26.
27
28.
29
PITCH VIBRATO
30.
31
32.
33
34
35
36.
37.
= Pitch in double vibrations.
= Intensity in millimeters
Space between vertical lines = One-tenth second
Space between horizontal lines = A semi-tone.

Fig. 3

cyclic in nature in order to produce the vibrato. It is due to the lack of configuration of pitch or intensity deviations that we describe these tones as having no vibrato, even though the amount of deviation is equal to that found in tones containing the vibrato.

TABLE V. *No vibrato*

		Pitch			Intensity		
No.		M.	E.D.	M.D.	M.	A.D.	M.D.
108		206	.21	.46	14	.04	.22
250		121	.12	.43	15	.09	.36
22		140	.14	.38	14	.02	.07
23		151	.11	.29	15	.04	.14
222		338	.17	.50	7	.04	.18
29		124	.13	.64	6	.06	.34
27		173	.16	.35	10	.02	.12
154		125	.21	.43	7	.05	.25
141		163	.72	1.26	14	.04	.24
140		125	.17	.43	6	.10	.38
252		163	.12	.26	14	.06	.23
254		134	.15	.56	10	.04	.23
172		140	.17	.69	15	.06	.20
25		140	.08	.29	12	.05	.20
28		173	1.03	2.00	13	.02	.09
51		419	.15	.38	9	.12	.60
109		351	.09	.45	9	.06	.38
120	256	266	.12	.37	4	.05	.13
125	256	251	.18	.50	4	.05	.25
139	220	207	.12	.33	4	.13	.20
26	220	207	.17	.25	19	.06	.26
24	220	205	.17	.42	11	.02	.10
207	220	193	.67	1.82	9	.04	.22
199	220	221	.17	.36	11	.05	.14
			.23	.58		.05	.23

Effect of Voice Placement on the Vibrato

In an effort to learn the effect of voice placement on the vibrato, five different types of voice placements were experimented with. Trained vocalists were asked to reproduce a tuning fork pitch of 220 d.v. in the following ways: forward, backward, nasal, throaty, and covered. The results recorded below show how placement influences the vibrato.

	Pitch		Intensity		Time	
	E.D.	M.D.	A.D.	M.D.	M.	A.D.
Backward	.18	.47	.08	.38	.15	.10
Nasal	.17	.41	.04	.21	.15	.06
Throaty	.28	.60	.13	.62	.16	.13
Covered	.23	.56	.11	.48	.15	.07
Forward	.23	.55	.07	.38	.16	.10

Since these computations are based upon five tones each, it is unwise to make unqualified statements concerning the influence of placement. Yet two tendencies are observable. The nasal placement, which produces the nasal quality, results in the smallest pitch and intensity fluctuations, the throaty placement, which results in strained and tense quality, has the greatest pitch and intensity fluctuations.

These two qualities are considered more or less objectionable by voice students, but the matter of amount of pitch and intensity deviations is not mentioned in voice literature. It is possible that this subject of extent of deviation may have a direct relationship with the pleasantness or unpleasantness of tone quality, which results from different types of placement.

			Pitch		Intensity			Time	
No.	Name	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
				Forward placement					
170	W.E.	219	.22	.52	8	.04	.18	.14	.07
18	G.J.	223	.27	.52	8	.08	.72	.16	.11
13	H.R.	226	.23	.59	14	.04	.22	.22	.09
190	E.E.	221	.22	.60	9	.02	.16	.16	.23
150	E.C.	443	.19	.54	7	.16	.63	.14	.00
			.23	.55		.07	.38	.16	.10
				Backward placement					
171	W.E.	216	.22	.52	11	.06	.10	.15	.06
41	G.J.	218	.17	.36	7	.09	.59	.15	.07
210	H.R.	226	.20	.59	16	.05	.21	.19	.09
191	E.E.	220	.17	.44	10	.04	.20	.15	.18
7	E.C.	435	.13	.44	7	.17	.70	.13	.11
			.18	.47		.08	.38	.15	.10
				Nasal placement					
34	W.E.	220	.22	.52	10	.01	.06	.15	.04
232	G.J.	219	.11	.28	7	.05	.31	.15	.08
33	H.R.	234	.13	.33	9	.06	.39	.16	.06
192	E.E.	220	.16	.36	12	.04	.24	.14	.10
35	E.C.	449	.21	.54	4	.04	.13	.15	.01
			.17	.41		.04	.21	.15	.06
				Throaty placement					
173	W.E.	217	.18	.36	8	.02	.26	.15	.08
233	G.J.	216	.38	.78	6	.19	1.05	.14	.06
15	H.R.	227	.34	.74	16	.09	.39	.12	.36
193	E.E.	220	.19	.52	13	.16	.72	.25	.06
10	E.C.	441	.30	.62	6	.17	.68	.14	.10
			.28	.60		.13	.62	.16	.13

Covered placement

174	W.E.	219	.19	.62	11	.05	.25	.14	.08
39	G.J.	222	.38	.64	8	.19	.68	.14	.07
214	H.R.	221	.18	.41	8	.05	.30	.15	.06
194	E.E.	220	.18	.60	17	.04	.19	.16	.09
14	E.C.	439	.20	.52	5	.20	1.00	.14	.05
			.23	.56		.11	.48	.15	.07

The Effect of Vowel Quality on the Vibrato

Proceeding as before, trained singers were asked to reproduce a tuning fork pitch on the vowels ä, ā, ē, ō, and ū. The results follow:

	Pitch		Intensity		Time	
	E.D.	M.D.	A.D.	M.D.	M.	A.D.
ä	.19	.50	.09	.33	.15	.05
ā	.21	.60	.07	.34	.15	.08
ē	.19	.46	.07	.23	.16	.08
ō	.21	.59	.10	.39	.16	.10
ū	.19	.44	.07	.30	.16	.09

The differences in pitch and intensity fluctuations, due to vowel quality, is very slight.

The Effect of Voice Registers on the Vibrato

Vocalists have divided the voice range into three registers, *i.e.*, head, middle, and chest. The chest tones represent, approximately, a little more than a half-octave interval in the lowest range of the voice. The head register consists of approximately the same interval at the top of the voice range. The interval of an octave, more or less, between the head and chest registers is known as the middle register. Only the head and chest tones were experimented with at this time, since practically all other tones of this study are of the middle register type.

Greater differences were found between the head and chest tones in regard to their pitch, intensity, and time fluctuations than between any other two groups of tones found in this study.

	Pitch		Intensity		Time	
	E.D.	M.D.	A.D.	M.D.	M.	A.D.
High tones	.24	.76	.08	.43	.15	.05
Low tones	.17	.44	.05	.28	.14	.10

Before any interpretation is made of these measurements something should be said of the relationship of amplitude to pitch frequency. *D. C. Miller* (9) presents the formula $(n A)^2$ and a graph in discussing this subject. "The intensity or loudness of a sound is proportional to the square of the amplitude multiplied by the square of the frequency, that is, to $(n A)^2$. A recording apparatus having ideal response must fulfil the following conditions: Let all tones of the musical scale, from the lowest to the highest, and all exactly of the *same* loudness, be sounded one after another and be separately recorded; let the amplitudes of the various responses be measured, and each amplitude be multiplied by the frequency of the tone producing it, then the squares of the products of amplitude and frequency must be constant throughout the entire series."

Miller accompanies this discussion with a graph in which he shows the actual amplitudes of sounds varying in pitch but constant in loudness. By actual measurement the amplitude of C^3 (259 d.v.) is 15 times the amplitude of C^7 (4,138 d.v.), yet the two tones are of equal loudness.

			Pitch			Intensity		Time	
No.	Name	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
				Head tones					
222	H.R.	338	.17	.50	7	.04	.18	..	..
38	G.J.	329	.26	.61	6	.13	.73	.15	.03
183	W.E.	329	.35	1.39	11	.09	.53	.16	.04
162	E.C.	896	.18	.54	8	.05	.27	.14	.08
			.24	.76		.08	.43	.15	.05
				Chest tones					
223	H.R.	113	.13	.36	8	.05	.27	.13	.00
250	E.C.	254	.22	.44	5	.04	.28	.14	.10
184	W.E.	135	.10	.64	22	.10	.47	.17	.16
38	G.J.	112	.28	.44	5	.04	.23	.13	.08
203	E.E.	108	.14	.46	7	.06	.27	.14	.07
208	E.E.	110	.18	.31	6	.03	.17	.14	.20
			.17	.44		.05	.28	.14	.10

Effect of Intensity Changes on the Vibrato

Trained vocalists were asked to reproduce the pitch of a tuning fork in the three following ways: pianissimo, fortissimo, and crescendo. Head and chest tones were avoided.

	Pitch		Intensity		Time	
	E.D.	M.D.	A.D.	M.D.	M.	A.D.
Pianissimo	.20	.50	.06	.30	.16	.09
Fortissimo	.20	.47	.09	.48	.15	.07
Crescendo	.35	.94	.07	.35	.16	.07

Since the crescendo begins pianissimo and ends fortissimo, it is not surprising to find that its intensity measurements approximate the average of the extremely soft and loud tones. The pitch measurements for the pianissimo and fortissimo are similar, but the crescendo tones are accompanied by excessive pitch fluctuations. Why the crescendo tones should not represent a compromise in pitch as in intensity is unaccountable. It is possible that the attempt to change the dynamics of a tone results in the loss of pitch control. The time measurements agree with those presented before. An increase in intensity is accompanied by a shorter pulsation rate, which means an increase in the number of pulsations per second.

Fortissimo

			Pitch			Intensity		Time	
No.	Name	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
16	H.R.	224	.28	.67	9	.11	.70	.16	.16
4	E.C.	457	.23	.43	4	.07	.41	.14	.09
185	W.E.	222	.17	.44	18	.09	.40	.16	.03
239	G.J.	218	.20	.44	8	.07	.39	.14	.07
204	E.E.	222	.10	.36	11	.10	.50	.13	.04
			.20	.47		.09	.48	.15	.07

Pianissimo

225	H.R.	221	.21	.44	6	.02	.14	.18	.08
165	E.C.	449	.11	.36	16	.09	.37	.14	.10
186	W.E.	212	.20	.52	8	.03	.16	.16	.06
41	G.J.	219	.25	.72	6	.13	.64	.14	.08
205	E.E.	221	.21	.44	6	.03	.19	.16	.12
			.20	.50		.06	.30	.16	.09

Crescendo

207	E.E.	193	.67	1.82	9	.04	.22	.18	.08
3	H.R.	230	.22	.59	11	.10	.49	.13	.07
51	W.E.	229	.17	.41	17	.06	.35	.15	.07
			.35	.94		.07	.35	.16	.07

The Effect of Voluntary Interference on the Vibrato

In an effort to learn what could be done with the vibrato in voluntarily exaggerating and eliminating it, trained vocalists were asked, in turn, to produce tones, with and without the vibrato. In the exaggerated vibrato, the vocalists were asked to make the pulsations as obtrusive as possible, while in the inhibited vibrato they were instructed to maintain a rigid and inflexible tone. The following measurements were obtained:

	Pitch		Intensity		Time	
	E.D.	M.D.	A.D.	M.D.	M.	A.D.
Exaggerated vibrato	.44	1.00	.13	.54	.14	.06
Inhibited vibrato	.20	.52	.12	.55	.15	.08

The exaggerated vibrato sounded like the "highly objectionable" tremolo. The pitch fluctuations produced are almost twice those of the normal vibrato. The intensity fluctuations are also exaggerated, while the attempt to make the pulsations obtrusive resulted in an increase in the number of pulsations per second.

The attempt to inhibit the vibrato was totally unsuccessful, since it was never accomplished. The pitch fluctuations for the "rigid and inflexible" tones resemble those for normal vibrato tones. The intensity readings are approximately the same as those for the exaggerated vibrato. Again, a very insignificant decrease in the pitch fluctuations is accompanied by an increase in the intensity fluctuations, which might be interpreted as a loss of intensity control. The rate of pulsation for the inhibited vibrato is slower than that of the exaggerated vibrato, but faster than the normal rate.

It is evident that the magnitude of pitch and intensity fluctuations may be increased beyond the habitual boundaries, voluntarily, with but little effort; but the attempt to reduce the pitch and intensity fluctuations below the habitual minimum is exceedingly difficult. Complete inhibition of the vibrato fluctuations was beyond the power of the vocalists in all cases here tried.

Inhibited vibrato

			Pitch		Intensity			Time	
No.	Name	M.	E.D.	M.D.	M.	A.D.	M.D.	M.	A.D.
216	H.R.	221	.17	.40	9	.08	.33	.13	.07
102	F.A.	133	.35	.69	11	.13	.47	.11	.10
104	J.W.	527	.26	1.33	7	.45	1.99	.15	.15
133	M.P.	541	.19	.35	7	.13	.54	.17	.04
156	E.C.	444	.11	.18	6	.04	.21	.14	.00
12	E.C.	443	.11	.26	10	.07	.32	.16	.05
21	W.E.	215	.22	.52	11	.07	.32	.15	.12
196	E.E.	221	.16	.44	14	.03	.18	.22	.13
			.20	.52		.12	.55	.15	.08

Exaggerated vibrato

2	F.A.	135	.57	1.30	13	.09	.43	.11	.07
42	J.K.	155	.59	1.82	16	.14	.57	.18	.16
44	M.P.	525	.64	.97	9	.33	1.13	.11	.07
155	E.C.	445	.28	.62	6	.12	.63	.15	.00
176	W.E.	216	.30	.76	8	.07	.29	.13	.05
19	W.E.	215	.44	.76	11	.08	.30	.11	.00
20	G.J.	229	.34	.78	12	.12	.63	.14	.07
195	H.R.	219	.18	.44	14	.04	.18	.19	.07
235	E.E.	217	.60	1.56	6	.19	.71	.15	.05
			.44	1.00		.13	.54	.14	.06

Influence of Age, Sex and Training on the Vibrato

1. *Age.* Seven children, ranging in age from eight to sixteen, with no special training in music, contributed tones for this section of the study. They were asked to sing tones which were well within their range and easy to sustain. These tones were photographed and measured. It was found that three of the eight children failed to produce any trace of the vibrato in their tones.

	Pitch		Intensity		Time	
Children	E.D.	M.D.	A.D.	M.D.	M.	A.D.
With vibrato	.17	.54	.09	.37	.17	.12
Without vibrato	.11	.42	.12	.54	...	...

The intensity fluctuations are smaller than those obtained from the tones of adult vocalists. In adult voices, however, tones devoid of the vibrato have smaller mean and maximum intensity deviations than tones containing the vibrato. The reverse of this situation is true in reference to the tones of children. Even though generalizations must be made with reservations due to the

limited sampling of children's tones, it appears that the child's voice is more flexible from the standpoint of intensity and less flexible than the adult's in regard to pitch.

2. *Sex.* The following data give some indication of the influence of sex. They include the measurements for trained voices only:

	Pitch		Intensity		Time	
	E.D.	M.D.	A.D.	M.D.	M.	A.D.
Female	.25	.76	.30	.80	.15	.07
Male	.22	.63	.26	.42	.14	.08

Men's voices do not fluctuate as much in either pitch or intensity as do women's voices. Of the total number of tones sung by trained men, 9 per cent were without the vibrato, while only 4.5 per cent of all tones sung by women were devoid of the vibrato. It might be said, then, that the vibrato is more conspicuous in women's voices than in men's and also more frequently present.

3. *Training.* Proceeding as before, we find the following measurements for the trained and untrained:

	Pitch		Intensity		Time	
	E.D.	M.D.	A.D.	M.D.	M.	A.D.
Trained singers with vibrato	.23	.56	.09	.36	.16	.08
Trained singers without vibrato	.21	.55	.06	.20	...	...
Untrained singers with vibrato	.20	.62	.08	.35	.15	.12
Untrained singers without vibrato	.26	.54	.05	.21	...	...

It is evident that the vibrato appears in the tones of the untrained as well as the trained singers; but, while the above data do not indicate the frequency of appearance on the basis of training, it was found that 93 per cent of all tones produced by trained vocalists and only 27 per cent of all tones produced by untrained singers, contained the vibrato. On the basis of training alone, it is possible to predict the presence of the vibrato with a high degree of accuracy.

The above data reveal only slight differences in the pitch fluctuations for the four types. There is a definite tendency, however, for the intensity fluctuations to be greater in tones containing the vibrato than in tones devoid of the vibrato, regardless of training.

The Vibrato Defined

Prior to the study of the writer on the nature of the vibrato, two factors were isolated and measured; namely, pitch and intensity. The third factor of the vibrato, that of time, was described as relatively constant. Not only was the time factor believed to be relatively constant, but the pitch and intensity relationship was assumed to be rigidly fixed and always parallel. The six conclusions as formulated by *Schoen* (16) reveal what was attributed to the vibrato prior to this investigation.

(1) "The vibrato is a fundamental attribute of artistically effective singing voice in that it is a medium for the conveyance of emotion in vocal-expression.

(2) "The vibrato is a manifestation of the general neuro-muscular condition that characterizes the singing organism.

(3) "The psychological effect of the vibrato is probably due to the fact that the human ear has, because of the behavior of muscle under emotional stress, come to associate trembling with emotional experiences.

(4) "The voice that possesses the most constant vibrato, constant in its presence in the tones throughout the range of the singer's voice and of an amplitude and intensity not obtrusive to the ear, but of sufficient intensity to be easily audible, has the best effect on the hearer, provided the other factors that enter into artistic singing are present.

(5) "The rate of the vibrato is relatively constant, of approximately six pulsations per second.

(6) "The intensity fluctuations are synchronous with the pitch fluctuations, wave by wave for both rate and extent."

The first four conclusions as formulated by Schoen stand unimpaired by the evidence submitted in this investigation, but the last two conclusions must be modified considerably, for it has been found that the rate of pulsations is quite variable and that the pitch and intensity relationship is not always parallel or synchronous.

In defining the vibrato, it is necessary to state that the vibrato consists of an observable periodicity of either pitch or intensity pulsations, or both, in a more or less regular time sequence or relationship, varying in rate of occurrence from 4 to 9 per second. It is a phenomenon of three variables; namely, pitch, intensity, and time.

Current Literature on the Vibrato

The vibrato has long been a subject of controversy among musicians and music critics. The literature on the subject is so confusing that it is next to impossible to glean a clear conception of the nature, causes, or desirability of the vibrato. Most of the literature available deals with the desirability of the phenomenon. Some critics maintain that it is desirable when not used excessively; others hold that even the slightest manifestation of it is objectionable.

In an effort to establish the status of the vibrato and tremolo, I shall resort to direct quotation from the works of voice critics on the subject. It must be borne in mind that these quotations are formulations of esthetic judgments and involve the desirability of the vibrato and tremolo primarily. Occasionally we find information or observations on how the vibrato is produced and what it attempts to accomplish.

In a recent work by *Lehman* (7) an entire chapter is devoted to the tremolo, which includes the vibrato. An attempt is made to differentiate between the tremolo and vibrato by making the amount of injury the vocalist suffers in producing them the chief criterion.

"Big voices produced by large, strong organs through which the breath can flow in a broad, powerful stream, are easily disposed to suffer from the tremolo, because the outflow of breath against the vocal cords occurs too immediately. The breath is sent there directly from the diaphragm instead of being driven by the abdominal pressure forward against the chest, the controlling apparatus, from whence it comes, in minimal pressure and under control, is admitted to the vocal cords. Even the strongest vocal cords cannot for any length of time stand the uncontrolled pressure of breath, that is, the direct breath pressure. One must learn to tense them by means of various muscular functions.

"The tremolo can also be produced by the false placement of the larynx which is not always fixed close enough under the nose and chin, and being disunited with e and u by means of y it wabbles around alone.

"Even the vibrato to which full voices are prone, should be nipped in the bud, for gradually the tremolo and later something even worse, is developed from it. Life can be infused into the tone by means of vowel mixing, a way that will do no harm.

"Vibrato is the first stage, and tremolo the second and more hopeless, which shows itself in flat singing on the upper and middle tones of the register."

The following quotation, taken from *Luisa Tetrazzini's* new book,(19) reveals the distinguished singer's attitude toward the tremolo:

"I am not going to attempt a catalogue of all faults which are possible, but name just a few: faulty intonation, faulty phrasing, imperfectly attacking notes, scooping up to notes, digging or arriving at a note from a semitone beneath it, singing out of tune and the tremolo. All of these faults are unforgivable, but the last two are crimes."

Thomas Edison (4) condemns the tremolo and the vibrato, too, by accusing most singers of breaking up their tones into a series of chatterings or tremolos.

"The number of waves varies from two to twelve per second. When at the latter rate, the chatterings can just be heard and are not very objectionable. If this defect could be eliminated, nothing would exceed the beauty of the human voice, but until this is done, there will only be a few singers in a century who can emit pure notes in all registers."

In discussing the beautiful voice of Jean DeRezské, *Herman Klein* (3) points out the following virtues: "His high notes produced with ease and always in perfect tune are magnificent in quality and as resonant as a bell. He sings without a suspicion of the tremolo," etc.

In the last few quotations it is evident that the term tremolo is used interchangeably with the term vibrato. It is unfortunate that voice critics use the two terms synonymously.

There are other voice students who might be quoted as being opposed to the vibrato, but the impression must not be conveyed that the vibrato is tabooed by all voice authorities. The vibrato is not without champions, for many able critics consider it an indispensable part of artistic singing.

"There is a desirable vibration or pulse in every tone which gives it life. This the old Italians called the vibrato; it is quite different from the tremolo. The vibrato is the natural pulse or rhythmic vibration of the tone, and in any attempt to keep the voice steady, this must not be lost; any control which presents this natural vibrato or life-pulse from entering the tone is bad."

This writer (21) has nothing more to say on the subject of the tremolo, except that it is bad. In general, critics who favor the vibrato do so because they feel that a voice without it is "cold, dead, and expressionless."

Rush (13) shows the relationship between the interval in pitch and the emotion conveyed.

"The presence of the tremulous voice is for the purpose of emotional expression. The tremor of the second and wider intervals, expresses states of exultation, mirth, pride, haughtiness, sneer, derision and contempt. The tremor of a semitone expresses suffering, grief, tenderness and supplication."

The vibrato, however, is not the only agency for the expression of emotion, as the following quotations disclose:

"As a general rule, pure tone should be used but there are emotions for the expression of which pure tone seems inadequate, and often inappropriate. Those emotions are more clearly suggested, more strongly impressed on the hearer by a quality more or less breathy, because the actual experiencing of these feelings induces such a quality in speech. In many passages indicative of eagerness, surprise, apprehension, dread and terror this will be found true" (6).

Finally,

"the majority of singers neglect the arduous training which is necessary to develop the will to express. Many pupils do everything their teachers have done, but do not feel; they copy. If they thought of that which they ought to give—if they felt it, they would awaken in themselves the desired means of expressing it, and so would rise to the demands of the author and public. Nothing will assist more the development of the power of expression than a careful study of mimicry and gesture" (20).

It is needless to say that the voice critics and students are more or less puzzled and confused in their thinking on this subject. They differ as to its desirability, nature, value, causes, and appeal. Yet the vibrato appears in the tones of trained vocalists, as this and other investigations conducted at the University of Iowa show. These researches have thrown considerable light on the nature of the vibrato, but the subject is practically unexplored and promises to be a most profitable field for acoustical, physiological and psychological investigation.

This investigation was originally conceived with the purpose of studying the effect of the emotions on the vibrato. Unfortunately, this objective was never realized, because the question of pitch and intensity relationship presented so many problems that required intensive study. However, positive light has been thrown upon a number of art principles and practices by this study.

Every photographic record reveals the fact that a normal tone is one in which both the pitch and intensity factors fluctuate. In trained voices the fluctuations are usually both regular and cyclic, while in untrained voices they are irregular and reveal no progressive tendency. But it must be remembered that both the trained and untrained voice fluctuates. This change in pitch and intensity is normal. No observer was able to produce a tuning-fork-like tone, rigid in pitch and intensity. Yet a few critics were quoted who insisted on steady tones. Voice critics who clamor for the steady tone should analyze the tones of their favorite vocalists with the aid of voice photography to convince themselves that virtuoso vocalists are unable to produce rigid tones.

In closing this section, reference should be made to the bitter controversy which Galli-Curci's initial appearance in London occasioned. It appears that her concert was an unqualified success financially. This was probably due to the advertising campaign which antagonized the music critics and resulted in a conflict between the principal musical magazines of London. Galli-Curci's most vicious critic was *Sorabji,*(18) who referred to her concert as " a sorry, sordid, and ridiculous business." One of the chief faults which he points out is her vibrato, of which he speaks satirically:

" —steadiness of tone, one of the most elementary requisites without which good singing does not even begin to exist, and as though one would have to listen to Galli-Curci to hear steadiness of tone. As who should say, ' Listen to Cortot when he plays a five-finger exercise, and see how he plays all the right notes.' "

This criticism was answered in the *Musical Times* (11). The writer, whose name is not revealed, comments on the artist's singing and commends her for the beauty of her " steady, clean vocal tone." Both critics heard the same voice and, yet, are unable to ascertain whether the vibrato was employed; and whether the effect was good or bad because of omission or commission. This episode shows something of the status of the vibrato and also that of musical criticism.

Turning next to the factor of intensity, we observe that this element has been ignored generally; yet it plays a coördinate

part with pitch in making for beauty in singing. . If a tone lacks flexibility in intensity, it is deficient in beauty. Just what can be done, in training an individual in intensty control, is a problem which has received little or no attention. Yet voice production involves more than pitch control alone.

In conclusion, it is fair to say that the art of singing is as yet based on no science of singing. The factors that constitute a tone are not clearly understood by critic or teacher. At the present time, voice teachers ignore the basic elements of time and intensity, in their desire to teach the skill required for the control of pitch. Scientific studies of the voice must be encouraged in order to reveal the true nature of the voice to the voice teacher and critic. Unfortunately, the voice teacher is unable to do this for himself, since it requires special equipment and training. Yet the voice teacher is dependent upon this information, for without it he cannot teach voice production.

Summary

1. The vibrato is a periodic phenomenon of three variables; namely, pitch, time, and intensity.

2. The vibrato is produced primarily by trained vocalists, although it is found in the tones of untrained singers; the rate of occurrence being 93 per cent and 27 per cent for trained and untrained, respectively.

3. Placement affects the extent of pitch and intensity fluctuations; the nasal resulting in the smallest and throaty production the largest for both factors.

4. Vowel quality reveals only slight influence on the vibrato.

5. Low tones show a relatively smaller amplitude and a faster rate of pulsation.

6. The vibrato may be increased or diminished by voluntary effort, but it cannot be inhibited or eliminated entirely.

7. Children's voices compare favorably with adult voices in respect to intensity fluctuations, but are relatively more rigid in regard to pitch fluctuations.

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