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Development of Vocal Performance in 5th Grade Children: A Longitudinal Study of Choral Class Singing

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ABSTRACT

The primary aim of the study was to assess the effects of choral class singing on vocal performance in primary school children. In particular, changes of the singing voice in terms of voice range profiles (VRP) and dysphonia severity index (DSI) were measured over the period of one school year. A further aim was to compare the effects of choral singing and regular music curriculum. A total of 50 5th-graders were assigned to two groups. Tuition of the choral singing group ($n = 32$) entailed a focus on singing in class as well as weekly 30-minute-sessions of special vocal training in small groups. Children in the regular music tuition group ($n = 18$), which also included singing, were given extra playtime. VRP and DSI were measured individually at the beginning and end of the school year. The two groups did not differ at baseline. Significant increases in the dependent measures were detected a year later in choral singing children only. There were no significant changes of vocal development in those children receiving regular music tuition. This study suggests that special training in choral singing supports children's vocal development. Singing education thus may have differential effects on vocal plasticity in post-lingual children.

INTRODUCTION

Choir singing as a widespread expression of music culture has been the object of a wide range of human interests including scientific research. Recently, empirical studies have begun to address the effects and relevance of choir singing in a professional as well as a non-professional context (for an overview see Kreutz, 2004). Ternström (1991), for example, took a psychophysical approach to combine the perspectives of vocal production, room acoustics, and psychoacoustic properties of the auditory system. In another vein, psychological effects of choir singing were observed in relation to perceived social- and health benefits (e.g., Clift & Hancox 2001; Bailey & Davidson, 2003). At a psycho-physiological level engaging in choir singing activity has been shown to positively influence emotional affect and local immune competence (e.g., Kreutz, Bongard, Grewe et al., 2004). The present work explores some of the developmental bases of these effects. In particular, we will address psychophysical indicators of vocal learning in 5th-graders aged 10 to 11 years using a longitudinal framework over a school year.

The physiological maturation of the human voice during childhood is subject to a large number of influences, which can affect the quality of individual vocal production. Medical research suggests a prevalence of voice disorders with an estimated incidence of 6 to 24 per cent among children (Connor, Cohen, Theis et al., 2008). Although the reliability of assessments may be questioned, highest levels of vocal performance quality are desirable for all children, because the human voice is without doubt one of the most important means of everyday communication and social interaction. Moreover, a well-functioning voice should play important roles in language acquisition and speech production. Recent findings suggest a beneficial association between the language and the music processing system, indicating a relationship of syntax processing in music and language with the implication of musical training as a potentially effective intervention in speech therapy (Jentschke, Koelsch, Sallat et al., 2008). In sum, there is growing acknowledgment of the importance of singing in general vocal pedagogy and therapy programs.

In several regions of the Federal Republic of Germany, so-called "choir classes" have been established in part as an attempt of education policy to overcome marginalization of singing education in public schools. Choir classes are conceptualized to provide wider opportunities for children to participate in specialized vocal training and thus to promote vocal education and healthy singing in public schools using a more project-type orientation. Curriculum topics within choir classes focus on singing and are complemented by weekly 30-minute-sessions of extra vocal training in small groups.

Previous research has shown that training of the singing voice can positively influence vocal development. Empirical studies comparing trained versus untrained voices have especially focused on differences in frequency- and dynamic range. For example, cross-sectional studies provide initial support for the assumption that singers possess higher ranges of fundamental frequency and voice intensity than nonsingers (e.g. Awan, 1991; Sulter, Schutte & Miller, 1995; Åkerlund & Gramming, 1994). Comparing singing and non-singing children, some investigations showed advantages for singers with respect to psychophysical voice parameters including frequency- and dynamic range (Berger & Walde, 2002; Fuchs, Heide, Hentschel et al., 2006). Finally, significantly lower F_0-aperiodicity during sustained phonation has been observed in children with special artistic vocal education as compared to children with regular education, which indicates better biomechanical vocal control in the former group (Dejonckere, Wieneke, Bloemenkamp & Lebacq, 1996). Few investigations, however, have studied the development of vocal efficiency parameters longitudinally. Some studies have shown an extension of frequency range and an improved control over the dynamics during vocal performance in adult's voices after a period of intense training (Le Borgne & Weinrich, 2002; Mendes, Rothman, Sapienza & Brown, 2003).

In the present exploratory study, we will compare groups of children from a choir class program to children that participate in regular music tuition that also entails singing. Its aims are two-fold, a) to examine the efficiency of a specific vocal training program, and b) to contribute more generally to a better understanding of vocal development in primary school children. Specifically, we ask: 1. To what extent does vocal training influence behavioural measures of vocal performance in relation to pitch and dynamics? 2. To what extent do groups of children who are enrolled in different music education programs benefit in terms of quality of vocal production? To address these questions, we assess several vocal production parameters that are considered as behavioural indicators of vocal quality and health in medical and phoniatric research.

METHOD

The study *in toto* entails two independent cohorts that are both investigated longitudinally. The cohorts differ in their individual socio-demographic background. Here we will report the results of the first school year of cohort 1 only, which is situated in a socio-economically weaker environment than is the case for cohort 2 (data not reported here).

A. Participants

Fifty 5th-graders (27 girls and 23 boys) from a German comprehensive school participated. Participants were assigned to two groups, the choral singing group (A, n = 32) and the regular music tuition group (B, n = 18) in a partially self-selected process (see limitations for a discussion). The upper part of Table 1 details the gender and age distributions for each group. All children received two lessons of music-tuition (à 45 minutes) per week. Group A received a music education program with a focus on singing in class, which was extended by weekly 30-minute-sessions of vocal training in small groups of 4 to 6 children. Vocal training in these settings was conducted by specially trained music education students. Children in Group B were given regular music education only, but no special voice training. Instead, those children received extra playtime, while Group A received vocal tuition.

Comparability of the two groups was established on the basis of similar gender and age distributions as well as similar overall school performance (Table 1). Chi-Square-Tests that were performed on the categorical data (sex, school recommendation, previous choral experience, parental education level) suggested that proportions of individuals within and across the two groups were indeed similar for these variables. School performance was quantified by individual recommendations for levels of secondary school provided by the teaching staff. In the German education system, children either will be assigned to a lower level education of 9 to 10 years, or they will be assigned to a higher level education of 12 years.

Interviews of parents and, in some cases, legal caregivers, were conducted to determine several aspects of the musical background. Participants of both groups featured comparable previous choral experience (PCE) (Table 1). Reported singing activity within the family was negligibly small.

The socioeconomic status of the parents/caregivers was assessed by means of the "International Standard Classification of Education" (ISCED) according to the procedures described in PISA 2003 (Züchner, Arnoldt, & Vossler, 2008). For the purpose of this study, two levels were constructed: level I (low) comprised parents falling into ISCED categories 0 to 4; level II (high) comprised parents falling into ISCED categories 5 and 6 (see Table 1).

Interviews of parents/caregivers also concerned voice disorders of the participants during the period of investigations. Only in group A parents of one girl reported a short-term inflammation of vocal folds that lasted one week and disappeared without medical treatment. As there were three cases of asthma in group B, those participants were excluded from analysis, resulting in n = 18 participants in group B.

Information about school recommendations and parental education levels was nearly complete with only one missing value for each category.

Table 1. Characteristics of the participant groups

	Group A	Group B
Sex	20 girls, 12 boys	7 girls, 11 boys
Average age	10;9	10;11
School recommendation		
9-10-y-edu	62.5 %	64.71 %
12-y-edu	37.5 %	35.29 %
PCE	46.88 %	33.34 %
PEL		
Level I (low)	16	9
Level II (high)	15	9

Note: Average age details years and months (x;y) of age for the two groups of participants. 9-10-y-edu = recommendation for lower level school education of 9 to 10 years: 12-y-edu = recommendation for higher level school education of 12 years. PCE = Previous Choral Experience; PEL = Parental Education Level (see text for further explanations).

B. Procedures

Voice range profiles (VRP) and dysphonia severity indices (DSI) of each participant were measured individually at the beginning and end of the school year as part of a multidimensional test battery including inventories concerning self-concept, emotion regulation and self-perception of voice quality. Results of the self-reports will be reported in future publications.

*1) Voice range profile (VRP).*VRPs have been suggested as a valuable aid in the description of vocal performance in adults as well as children (Gramming, 1988; Schutte & Seidner, 1983; Coleman, 1993; Åkerlund & Gramming, 1994; Awan, 1991; Sulter et al., 1995; Le Borgne & Weinrich, 2002; Böhme & Stuchlik, 1995; Wuyts, Heyler, Mertens et al,. 2002).

The VRP (also known as phonetogram) consists of two curves showing the sound pressure level (SPL) of softest and loudest phonation as a function of fundamental frequency (F_0) throughout the pitch range. Frequency range is conventionally plotted horizontally, while intensity is displayed along the vertical axis of the VRP. Thus VRPs do not only reflect vocal frequency an intensity capabilities, but also the interaction between these variables (Wuyts et al., 2002).

SPL measurements of the singing voices in dependence of the frequency deliver relevant information about the volume and pitch ranges of the voice and therefore represent a useful tool for assessment of vocal performance especially by plotting vocal change across time. As VRPs define the physiological limitations of a voice, they may serve to quantify the amount of vocal maturation.

In the present study VRP recordings were performed using the DiVAS voice diagnostic measuring system (v2.1 XION medical GmbH, Germany). The recording and assessment procedures mainly followed the recommendation of the Union of European Phoniatricians (Schutte & Seidner, 1983).

All participants were informed about the procedure before recordings. Data acquisition took place in a quiet, separate room without special acoustic preparation. This environment was chosen, to enable the participants to use a normal amount of perceptuo-motor-control that would have been compromised in a sound-proofed cabin, for example (Schutte & Seidner, 1983).

Each participant was standing throughout the data acquisition period, wearing a headset with a sound level meter attached to a boom at a distance of 30 cm in front of the mouth. This arrangement keeps the distance and position of the microphone relative to the mouth constant, while still allowing the participants to move their heads. An integrated electronic circuitry calibrates the microphone connection automatically such that measurements took place under defined and reproducible conditions. Fundamental frequency was recorded in Hertz (Hz) and sound pressure levels were measured in decibels (dB(A)). All VRPs were completed by a single investigator with many years' experience of voice education in children.

Every target note was presented for repetition by the investigator on the vowel [a:]. Recordings always started with softest phonations, as non-professional singers often are not able to relax fast enough after maximal strain of loudest phonation (Nawka, Franke & Galkin, 2006). Measurements started approximately at mean fundamental frequency of the speaking voice, which was determined individually by DiVAS speaking voice profiles (counting from "twenty-one" upwards) at the beginning of each recording. Beginning at a middle pitch, recordings of the singing voice continued with higher pitches in ascending order up to the uppermost frequency and concluded with the lower pitches which were recorded in descending order down to lowest frequency possible. Afterwards the same procedure followed for high-intensity voice production.

The upper and lower contours of intensity were completed for every tone of the C major scale within the child's pitch range. Concerning the highest and lowest frequency possible, also semitones beyond the C major scale were permitted to record the pitch range precisely. To obtain the desired pitch it was often necessary for the experimenter to repeat the target pitch a several times or to ask the child to glissando from a comfortable midrange frequency to the given tone. To make clear the task of singing with highest/lowest intensity possible, the investigator always demonstrated an example of soft/loud phonation. A tone was considered acceptable only, if phonation modus was different from screaming or whispering.

The same procedure was carried out for the first investigation at the beginning of the school year (Oct. 07) and for the second recording at the end of the school year (June 08).

2) Dysphonia severity index (DSI). The DSI as a multiparametric method represents a suitable tool to estimate overall voice quality objectively and was developed by Wuyts, De Bodt, Molenberghs et al. (2000). DSI has been found to correlate with parameters of vocal complaints and voice disorders (Kooijman, de Jong, Oudes et al., 2005). Furthermore this index has been used to compare voice quality of different groups of speakers (Timmermans, De Bodt, Wuyts et al., 2002) and to asses outcome of voice training programs in adult professional voice users (Timmermans, De Bodt, Wuyts et al., 2004).

This index consists of a specific weighted combination of acoustic parameters that correlate with several aspects of voice quality: Highest fundamental frequency (F_0-max), lowest intensity (I_{min}), maximum phonation time (MPT) and jitter. The DSI is constructed as

$$DSI = 0.13 \times MPT + 0.0053 \times F_{max} - 0.26 \times I_{min} - 1.18 \times jitter (\%) + 12.4.$$

The resulting DSI values range from negative to positive scores. It is constructed such that a normal voice quality corresponds with a value of +5 and a voice with severe dysphonia corresponds with value of –5 (Wuyts et al., 2000). Scores beyond that range are of course possible as they are indicating good or poor voice quality (Hakkesteegt, Brocaar, Wieringa et al., 2006).

In the present investigations DSI data recordings were also performed using the DiVAS voice diagnostic measuring system. F_{max} and I_{min} are automatically taken from the VRP. MPT recordings were obtained by asking all participants to sustain an [a:] for as long as possible at a comfortable pitch and loudness. Recording conditions were identical with VRP recordings (normal room acoustics, use of microphone headset, comfortable standing posture). The percentage jitter was calculated on the recordings of MPT, starting approximately half a second after voice onset.

C. Data Analysis

Pitch range can be determined from upper contours (forte curve) as well as from lower contours (piano curve) of the VRP. Frequency values were converted into semitones to yield pitch range. Thus the number of semitones was detected related to both piano and forte curve for every participant individually concerning both test intervals t_0 (beginning of school year) and t_1 (end of school year).

To calculate an average dynamic range for every participant, the dB SPL values of the piano curve were substracted from that of the forte curve for every single frequency of the C major scale within the child's frequency range. This procedure was carried out only for those frequencies that featured a pair of dB SPL values (those cases, a child was able to produce the target pitch with both loud and soft phonation). These difference-values were averaged across the recorded frequency-pairs. Thus a value of average dynamic range (in dB SPL) was obtained for every participant. The same procedure was carried out during both test intervals t_0 and t_1.

For the quantitative assessment of our research questions, SPSS program release 16.0.2 for Windows was used. To examine the effects of vocal training on vocal quality measures as well as the changes of vocal performance variables over time, repeated measures analyses of variance (ANOVA) were performed using the general linear model (GLM) algorithm of SPSS. Participant group (A and B) and sex served as between-subject variables, whereas time of data acquisition was the repeated measures variable. This analysis was individually applied to several dependent variables (pitch range of forte curve and piano curve, dynamic range and DSI).

A one-factorial ANOVA was performed for every dependent measure to determine if there were significant differences between the groups at the baseline survey and at the end of the school year.

To control for possible influences of parental education level (PEL) and previous choral experience (PCE) on the four dependent measures, these variables were included in additional repeated measures ANOVAs to see whether the initial results were affected. The alpha level was set at 0.05 for all analyses.

RESULTS

Table 2 represents the results from repeated vocal performance measures of pitch and dynamic ranges as well as overall vocal quality (represented as dysphonia severity index) across one school year.

Table 2. Means (and standard deviations) of group A (choir class) and B (regular music tuition) for each of the dependent measures across the two points (baseline and end of school year).

		Group A	Group B
PR forte	baseline	20.31 (3.02)	19.22 (3.61)
	end of school year	26.56 (3.43)	19.06 (3.10)
PR piano	baseline	20.69 (2.87)	20.17 (2.50)
	end of school year	25.94 (3.68)	19.17 (2.79)
DR	baseline	9.73 (4.07)	7.69 (2.58)
	end of school year	15.75 (4.34)	7.38 (2.64)
DSI	baseline	4.42 (1.16)	4.11 (1.14)
	end of school year	6.08 (1.43)	4.22 (1.22)

Note: PR forte = pitch range of loud singing in semitones; PR piano = pitch range of soft singing in semitones; DR = dynamic range in dB(A); DSI = dysphonia severity index (see text for details).

Table 3 summarizes the results the repeated measures ANOVAs for the four dependent measures. There were no significant effects of sex in any of these analyses. Therefore this variable was excluded. As can be seen, similar patterns of effects were observed indicating changes of vocal performance measures over time which affected the experimental group only.

Subsequent one-factorial ANOVAs revealed that the pitch and dynamic ranges as well as the mean DSI values of the two groups did not significantly differ at the beginning of the school year. Thus conditions for both groups were comparable at the baseline.

Table 3. Summary of F-values and effect sizes from repeated measures analyses of variance on the four dependent measures.

	dF	Time	Group x Time
		F (partial η^2)	F (partial η^2)
PR forte	(1; 46)	63.51*** (.580)	75.42*** (.621)
PR piano	(1; 46)	20.82*** (.312)	48.43*** (.513)
DR	(1; 46)	27.47*** (.374)	33.29*** (.420)
DSI	(1; 46)	23.01*** (.333)	17.78*** (.279)

Note: PR forte = pitch range of loud singing in semitones; PR piano = pitch range of soft singing in semitones; DR = dynamic range in dB(A); DSI = dysphonia severity index (see text for details).***** p < .001**

Post-intervention pitch ranges differed significantly between both groups for the forte curve [F(1;49) = 59.15, p < .001] and piano curve [F(1;49) = 45.89, p < .001]. Group A significantly increased their pitch ranges in both forte and piano curve by 6.25 and 5.25 semitones, respectively.

The one-factorial ANOVA concerning dynamic range at the end of the school year showed that groups differed significantly with the experimental group having higher values than the controls [F(1;49) = 55.31, p < .001]. In particular, in group A, the mean difference was 6.02 dB SPL.

A. Dysphonia Severity Index (DSI)

Figure 1 depicts the interaction effect between group and time for the mean scores of the DSI as derived from Table 2.

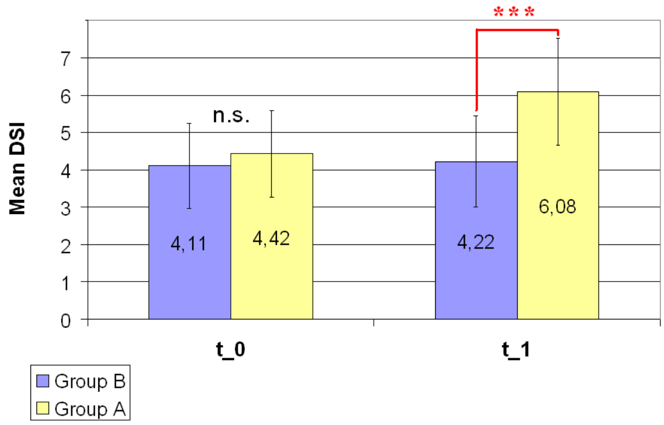

Figure 1. Mean scores (and standard deviations) of the DSI produced by the participants of group A (choir class) and group B (regular music tuition) at the beginning of the school year (t_0) and at the end of the school year (t_1). *** p < .001

There was a significant difference between groups at the end of the school year [F(1;49) = 21.66, p < .001]. Participants in group A improved their average DSI score by gaining 1.66 points, whereas participants in group B did not improve considerably, the mean difference being 0.11 points.

B. Parental Education and Choral Experiences

PEL did not produce any significant main effects on pitch and dynamic ranges. However a significant between-subject effect concerning the DSI was detected [F(1;45) = 4.69, p < .036, partial η^2 = .094]. Children whose parents had higher educational backgrounds scored better on the DSI.

However, there was no effect of PEL on pitch and dynamic ranges, neither did PEL interact with group or time. This means that parental education had no influence on the improvement of the four dependent measures over time.

Children with choral experiences differed systematically from children without such experiences as represented in significant main effects of this variable on pitch range (piano: [F(1;46) = 3.01, p < .089, partial η^2 = .061]; forte: [F(1;46) = 7.14, p < .010, partial η^2 = .134]) and dynamic range [F(1;46) = 6.98, p < .011, partial η^2 = .132]. However, there was no effect of PCE on DSI, neither did PCE interact with group or time. This means that PCE had no influence on the improvement of the experimental group children in the four dependent measures over time.

DISCUSSION

The present investigation addressed the longitudinal effects of a choral singing program at a comprehensive school. In particular, we asked to what degree vocal training might affect vocal performance measures in 5^{th}-grade children. To the best of our knowledge, this is the first study to examine vocal development in terms of vocal pitch and dynamics longitudinally over the course of a school year while comparing groups of children that were or were not enrolled in special singing training classes. Significant differences between the two groups in terms of quantitative vocal performance measures emerged. These observed differences imply that vocal training may have caused changes in voice quality that could not be seen in children without training. Although these patterns of changes were similar with respect to different vocal performance parameters and even extended to a clinical index of vocal functioning, the dysphonia severity index, we will discuss the varying implications of observations for each of these parameters in turn.

A. Pitch Range

The results in both loudest and softest phonation of the VRP make clear, that children in choir classes could considerably expand their pitch range as a function of vocal training, whereas children in the regular music tuition group failed to increase the upper and lower limit of their pitch range.

Expansion of pitch range in choir class children could be explained by a more effective use of the laryngeal and respiratory system and a better muscular and sensory control. The observation that pitch range increased more in loudest than in softest phonation (6.25 vs. 5.25 semitones) can be made plausible considering the experience of singers and vocal pedagogues reporting that performance of piano or pianissimo phonation is one of the most difficult tasks in voice production. “The ability of a singer to maintain minimal intensity while maintaining frequency requires exquisite coordination of respiration, phonation and resonance.” (Le Borgne & Weinrich, 2002). For this reason it is remarkable that vocal pitch flexibility for soft tones increased by more than 5 semitones. A general increase of approximately 5-6 semitones in vocal pitch range within one school year may be regarded as a considerable progress, especially when longitudinal investigations of adults are considered. Le Borgne & Weinrich (2002), for example, report an increase of 1.38 semitones for trained singers over a nine-month period of vocal training, Mendes et al. (2003) showed an expansion of 5.7 semitones for college voice majors within four semesters of voice training. Conversely, it may be assumed that the stagnation of pitch range within group B may be caused by not being able to use full capacity of the phonatory mechanism.

The observed mean pitch ranges at the end of the school year (group A: 19.06 semitones group B: 26.56 semitones) are in accordance with previous cross-sectional findings concerning the pitch range of trained and untrained children. Fuchs et al. (2006) specified pitch ranges of untrained boys (age 11-13.5 years) as 18.9 semitones and untrained girls (same age range) as 22.3 semitones. Within the same investigation the authors observed mean pitch ranges of 26.5 semitones for trained boys and girls of the same age range.

B. Dynamic Range

A further result was the ability of children in group A to significantly improve their vocal dynamic control. In particular, children with vocal training gained 6.02 dB SPL on average, whereas dynamic range of participants in group B remained nearly constant. Note that an increase of approximately 10 dB corresponds with a doubling of perceived loudness (Terhardt, 1998). As further longitudinal investigations of adult solo singers education (4-5 years) on the SPL of loudest phonation showed an increase (across participants, vowels and pitches) of 2.4 dB (Mürbe, Sundberg, Iwarsson et al., 1999), a difference of approximately 6 dB within one school year may be regarded as a considerable progress. The ability to perform with significantly greater dynamic flexibility may indicate improved coordination of respiration and phonation, especially concerning an improved interaction between subglottic pressure and vocal fold strain.

C. Dysphonia Severity Index (DSI)

A significant increase of DSI values was found for children in group A only, which indicates an improved voice quality due to the voice training. The DSI score changed from 4.42 to 6.08 for group A and from 4.11 to 4.22 for group B.

These findings are of particular importance, because they imply a role of vocal training not only in relation to an enhanced functioning for the benefit of musical and aesthetic goals. Furthermore, as the patterns of changes are of relevance using a clinical index of vocal health, it can be assumed that vocal training may have preventative vocal health implications. This interpretation is, in part, supported by the fact that none of the children participating showed voice related health problems as reported by the parents and their vocal performance measures.

Nawka et al. (2006) state that a normal voice quality corresponds with a value of $DSI > 4.2$. Thus DSI of all participants seem to be within the range of normal values. To the authors’ knowledge normative DSI values for children are presently unknown, but are documented only for adults (Hakkesteegt et al., 2006). The test-retest variability of the DSI in adults has been examined (Hakkesteegt, Wieringa, Brocaar et al., 2008). Results showed that differences in DSI within one subject need to be larger than 2.49 to be significant. This observation suggests a limitation of the present results, because differences of 1.66 were already statistically significant. While age has been shown to have an effect on DSI for adults (Hakkesteegt et al., 2006), similar data for children are lacking. In sum, we must accept the significance of the present results as the patterns of changes were similar for all vocal performance measures.

Higher parental education was associated with superior DSI, suggesting an influence of the socioeconomic status of the parents/caregivers on resources of vocal health. However, this systematic difference among the children did not affect the improvement in vocal performance, as the increase of the investigated variables did not interact with parental education.

Consistent with expectations, children’s previous choral experiences significantly influenced the total scores of vocal efficiency parameters (pitch ranges of loud and soft singing and dynamic range). However, changes in vocal efficiency were found independent of earlier participation in choir singing.

D. Limitations

Limitations of the present study must be considered with respect to the relatively small sample size of participants and the partial self selection of the experimental and control groups. Although the assignment to the experimental group was left to chance and no attrition was noted overall, children enrolled in the choir class have been chosen among those, whose parents signed up for this specific vocal pedagogy program. This selection does not in all cases represent the desire of the children, as 21.9 % of the children in the choir class reported that it was not their own wish to attend.

The external validity of these explorative results may be further limited to the selection of participants under special environmental influences. Further investigations are needed to assess the influence of context factors such as, for example social environment.

On the basis of this study it is not possible to determine whether the progress occurred as a result of specific training elements. It remains to be determined whether the significant differences found in this study are due to single or multiple aspects of the intervention.

Finally, the present findings are restricted to one particular age range, while it is still unclear what might be the most appropriate age for children to be submitted to vocal pedagogy programs. It is possible that younger children may especially benefit from vocal training.

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