



VISUAL FEEDBACK APPLIED TO THE LEARNING OF CONSCIOUS PITCH CONTROL IN SINGING

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ABSTRACT

Recent research suggests that singing ability can be characterised by certain stages along a continuum of ability. Development of singing ability along this continuum can be readily assisted by the use of appropriate visual feedback. This paper describes a system working on a BBC microcomputer which enables note pitching accuracy to be developed and assessed. It incorporates a specially developed hardware interface which estimates voice fundamental period in real-time without output smoothing. Whilst it is intended that the system be used with any age group, a recent pilot study has concentrated on classes of primary school children and the results obtained support its use for the development of conscious pitch control. The findings have implications for other areas of voice development in which vocal pitch is significant.

INTRODUCTION

Many people derive much pleasure from taking part in some form of singing performance. Others would like to be able to take a more active part but their level of ability or lack of confidence may prevent them attaining an appropriate standard. One major aspect which limits active participation in singing is the ability to successfully pitch a note against a reference; an essential skill if one is to perform. Recent research has indicated that this skill can be developed if one is willing to put in the necessary practice and if appropriate tuition and feedback are available. Traditionally, this feedback would come from a music teacher or perhaps a trusted colleague, but developments in electronics and especially in microcomputers offer new possibilities for self-assessment and development via visual feedback.

This paper describes a system designed to provide such feedback for vocal pitch matching development. Pilot experimental work with groups of young children has already been undertaken which demonstrates the system's usefulness in the classroom. The system has been titled "SINGAD", which stands for SINGING ASSessment and Development. It requires a BBC model B, B+ or Master microcomputer and it operates in conjunction with a specially developed hardware interface box which picks up sung or spoken sounds with its internal microphone and processes them to provide a fundamental frequency input to the computer. The SINGAD system has been designed for use with all ages from about five upwards, but

present work has concentrated on those of primary school age.

SINGAD has been designed to match the level of operation to the individual's singing skill using first a blank screen where there are no visual pitch targets, through to a screen with up to four picture targets, and for the musically experienced, a screen with a treble or bass staff. The system is also able to assess vocal pitching accuracy by playing notes which the user is required to sing, and then analysing the fundamental frequency of the sung versions against the notes played. By this method, some quantitative record can be made which allows the development of pitching skills to be followed over time.

The use of systems such as SINGAD is not seen as a threat to the livelihood of professional singing teachers and voice coaches. SINGAD is intended to give the student benefits in practice sessions with the development of more fundamental aspects of singing performance which are quantifiable, and in some cases, more readily accessible from the de-personalised feedback provided from computer-based systems. The professional voice trainer is then left with more time which can be devoted to essentially unquantifiable skills such as musical performance and interpretation.

BACKGROUND

In children of all age groups there are some who find it difficult to pitch a note against a reference tone. They have been termed 'poor pitch' or 'uncertain' singers, e.g. [1], and more recently, 'developing singers' [2]. The development of singing may be thought of as a continuum of ability [3, 4, 5] from those who are just beginning to control vocal pitch contours consciously at one end to those who exhibit a multi-faceted singing ability, such as being able to sing 'at sight'. A variety of ability is 'normal' within any given age group and is indicative of different stages along the continuum.

The improvement of vocal pitch matching ability is dependent on several factors. Movement along the developmental continuum can be facilitated if the teacher adopts appropriate educational strategies [2, 6]. For example, children should (a) be encouraged to explore vocal pitch contours across pitches, starting from high to low; (b) match individual pitches within a relatively limited range, such as A3(220Hz) to A4(440Hz) for infants school age children; and (c) experience internal matching and simple pitch patterns from a variety of starting pitches within these ranges.

In each case, the central principle is that the task allows the children to extract 'appropriate' feedback about their individual performance. In order for it to be 'appropriate', the developing singer must be able to extract and use the information provided. This aspect poses particular problems in the classroom situation, where there may be thirty or more children at different stages along the developmental continuum and the teacher may have no background in voice skills development. If a child is to develop conscious pitch control, then the task must make sense and must provide some standard against which the child can rate his/her performance. Earlier research suggests that successful use can be made of visual feedback to give an external correlate of performance for children who are unable as yet to generate an internalised criterion reference [e.g. 6, 7].

The SINGAD system has been designed for the assessment and development of vocal pitch matching. In particular, it has been aimed at the primary school classroom, but it also incorporates features which make it potentially useful for experienced singers developing advanced skills such as vibrato, controlled note onset and offset, and the pitching of non-western intervals.

#### SINGAD HARDWARE

The SINGAD system [8, 9] has been designed to give visual feedback of vocal pitch to the singer, and it was initially intended for use in a classroom. It makes use of the BBC model B, B+ or Master microcomputer, which is ubiquitous in primary and secondary schools, in conjunction with a purpose designed software package, and a specially developed hardware interface to estimate the fundamental period of voiced sounds, whether spoken or sung.

The heart of the SINGAD system is the hardware interface which was originally developed for use in advanced hearing prostheses. The device operates in real-time by time domain peak-picking with no output smoothing [10, 11]. It derives its power from the computer and it is packaged in a small (currently 110 X 45 X 70mm) box with an internal microphone.

Visual feedback is only of real benefit when it can be provided in real-time because it is only then that a correlation can be established between pitch production and the visual image. Notes produced by young or the more inexperienced singer, who often lack confidence in the early stages, will often have a broken-up or rough voice quality and the lack of device output smoothing ensures some visual feedback is available. It is important that any device to be used in a school environment is designed to be reliable and easy to use. The SINGAD hardware interface simply connects to the BBC 'user port' and there is only a 'gain' control to adjust which is readily set.

#### SINGAD SOFTWARE

There are two phases in the SINGAD menu-driven software: assessment and development. The features of each stage have been described in detail elsewhere [8, 9] and only a brief description is given here.

The assessment phase, which may be used at various stages during work with the system, enables up to ten test notes to be presented in a random order from the computer's internal loudspeaker. The subject's sung response to each is measured by the computer. The absolute differences between the sung fundamental frequency values as estimated by the peak-picker, and the fundamental frequency values of the notes played are then calculated in octaves and semitones, and a mean score is given as a summary statistic (e.g. see figure 1). The test notes are derived from either a treble or bass pitch range. In each range ten stimuli, consisting of the 'white' notes on a keyboard, are available. These are for the treble range A3(220Hz) to C5(512Hz), and for the bass range B2(123Hz) to D4(293Hz). These notes chosen for the ranges have been selected with reference to the ranges used naturally by poor pitched singers, and the fundamental frequencies of the BBC generated stimuli have been confirmed by spectral analysis [8].

The development phase makes use of a real-time plot of the logarithm of fundamental frequency against time (set by the user as 4, 8, or 12 seconds for a full screen sweep) which tracks along the bottom of the screen during non-pitched sounds. Picture targets can be provided on the screen to increase the level of difficulty of the pitching task, depending on the user's stage of singing development. Current possibilities include: a blank screen; a screen with 1, 2, 3 or 4 pictures (e.g. see figure 2); a screen with a single picture target which is associated with an auditory target in the form of a note played by the computer; a treble staff; and a bass staff (e.g. see figure 3). Whenever picture targets are in use, their position on the screen can be juggled either at random or by hand to establish a different target pattern of pictures.

#### THE SINGAD SYSTEM IN USE WITH CHILDREN

An initial trial with the SINGAD system in a London primary school [12] indicated that (a) the system appeared to function as intended, (b) the children were able to use the system to improve their vocal pitch matching, and (c) they enjoyed doing so. This first study was mostly concerned with the initial development of the SINGAD hardware and software, and time constraints kept the sample size small.

A later study made use of a larger sample (N=32) of seven year-olds, and it was carried out in a Bristol primary school [13, 14]. The SINGAD assessment phase was used to measure the children's ability to sing in-tune at the outset of the pilot study. The sample was then divided into three statistically matched groups in terms of observed vocal pitch accuracy. These were; (a) a control (CO) group (N=11) who continued their usual music learning programme; (b) an experimental interactive (EI) group (N=10) who were given regular SINGAD development sessions with their teacher; and (c) an experimental non-interactive (ENI) group (N=11) who used the SINGAD development software with no adult interaction. All children using the SINGAD development phase worked in pairs over seven weekly ten minute sessions, and were given a familiarisation session with the system prior to the initial SINGAD assessment.

At the end of the seven weeks, all three groups of children were tested again using the SINGAD assessment software, and the results were subjected to an analysis of variance and t-tests. Results showed a highly significant difference between the final and initial assessments due to the significant improvement of the two experimental groups. Adult interaction (for the EI group) had the effect of marginally enhancing vocal pitch matching development compared to the group using the system on their own (ENI), but both groups were now significantly more accurate than the control group. Moreover, these improvements were maintained over time as judged by a further re-assessment six months later. So it would appear that SINGAD can be used successfully in the classroom, with or without the intervention of the teacher as it is rarely possible to give individual attention to all children.

#### CONCLUSIONS

A system which enables singing ability to be assessed and developed is described. It makes use of a standard BBC model B, B+, or Master microcomputer, a specially developed hardware interface, and menu-driven software. The system has been used with a group of 32 seven-year-olds in a Bristol primary school and results suggest that it enables children to develop conscious control of vocal pitching skills to a greater extent than conventional class music teaching. This development need not require the supervision or interaction of an adult. Further studies are currently in progress which will investigate the usefulness of the system over the course of a school year.

It is proposed that such systems could be used as a part of singing training to enable the student to make more efficient use of practice time. Other acoustic features of the trained and untrained voice have been investigated [e.g. 15, 16] which also lend themselves to incorporation in real-time visual feedback systems. The intention behind such developments is not to in any way replace the function of the professional voice trainer but rather to enable the student to have additional help with some of those aspects of voice training which can be quantified. The teacher then has more time to devote to those essentially unquantifiable aspects, such as musicality, stage presence, performance, interpretation, vocal colour and intonation which all too often are left until the last few precious minutes of each lesson.

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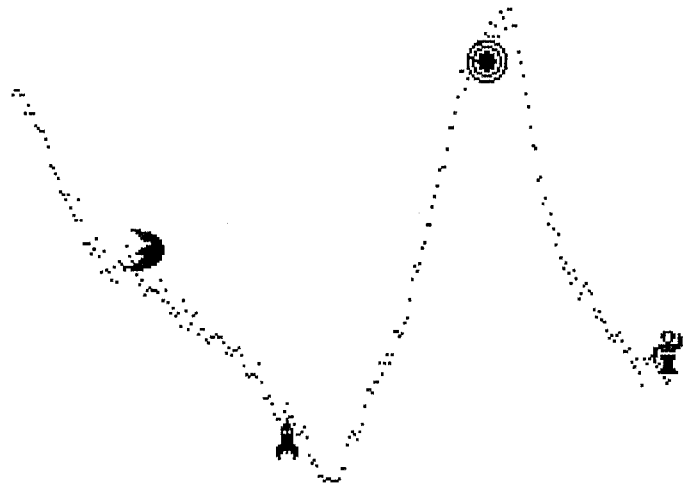
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SINGAD ASSESSMENT RESULTS TABLE  
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 (C) DMH & CB (Vers: 2)  
 Bass range; 10 notes; Len: 1s; Vol: 12/15.

DMH TEST1 Feb 1989  
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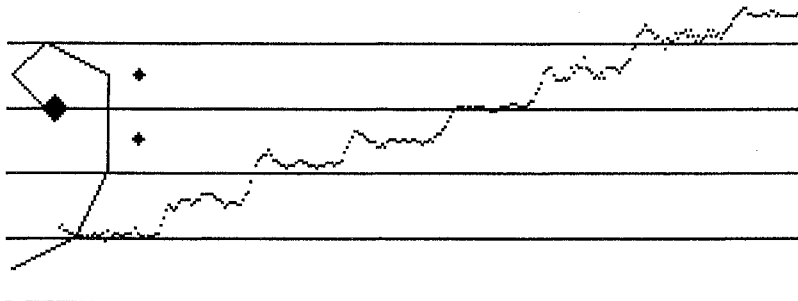
| Test (Hz)           | Sung (Hz) | Oct dif | S/tone dif |
|---------------------|-----------|---------|------------|
| 167.700             | 168.492   | 0.007   | 0.082      |
| 266.300             | 269.833   | 0.019   | 0.228      |
| 224.300             | 226.603   | 0.015   | 0.177      |
| 125.700             | 124.580   | -0.013  | -0.155     |
| 133.300             | 133.138   | -0.002  | -0.021     |
| 251.300             | 254.194   | 0.017   | 0.198      |
| 178.000             | 178.571   | 0.005   | 0.055      |
| 149.700             | 148.787   | -0.009  | -0.106     |
| 299.900             | 303.582   | 0.018   | 0.211      |
| 199.600             | 200.602   | 0.007   | 0.087      |
| ABSOLUTE MEAN DIFS: |           | 0.011   | 0.132      |

FIGURE 1: Example SINGAD assessment results table.



**J(ug); SPACE=go; O(lap); ESCAPE (4s)**

FIGURE 2: Four pictures with pitch trace (SINGAD development)



**SPACE=go; O(lap); ESCAPE (4s)**

FIGURE 3: Bass staff display with sung scale pitch trace.