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THE ASSESSMENT AND DEVELOPMENT OF SINGING ABILITY - INITIAL RESULTS WITH A NEW SYSTEM

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ABSTRACT

The system described is designed to allow the quantification and development of vocal pitch matching. It uses a BBC microcomputer with a specially designed interface which estimates voice fundamental frequency from an acoustic input. A session with this equipment would normally involve an assessment phase, a development phase followed by a second assessment phase thus enabling the effectiveness of training to be monitored at each session. The discussion presented is from a pilot study to optimise the system.

INTRODUCTION

The literature on children's singing reveals that, within each age group, there are some children who have difficulty in vocal pitch matching termed 'poor pitch' or 'uncertain' singers (for review, see [1], [2], [3]). Typically, the percentage of such children within sample populations decreases with age, with a ratio of boys to girls of 2 or 3:1. The most recent research indicates that singing may be regarded as a developmental continuum of behaviour ([4], [5], [6]). A variety of singing expertise, therefore, should be regarded as normal for any given age group, being indicative of children at different stages of singing development.

Improvement in singing ability in general, and pitch accuracy in particular, is dependent on several factors. The above researchers indicate that teachers can assist this development if (a) they require the children to sing within a limited pitch range, e.g. infants aged 4-7 using the range A(220Hz) to a(440Hz), and juniors using G(195Hz) to d'(560Hz); (b) the children are allowed to experience sufficient variation within this pitch range, as accuracy is a product of having to meet the same pitch task (e.g. a falling third) across a variety of pitches; and (c) the children are able to extract meaningful feedback from the singing task.

For vocal pitch to come under the conscious control of the child, s/he must be able to make sense of the task. Implicit in this is the child's ability to rate performance against some standard. If the child is unable to generate an internalised criterion of performance (perhaps through a lack of previous success, not understanding the task, or a lack of meaningful feedback), it may be possible to provide some external correlate which the child can make sense of, through visual feedback. This has proved particularly successful in early stages (e.g. [9], [10], [11], [12]) where the researcher provided some general information as to the degree of pitch accuracy through arm movements, or through the illumination of coloured lights.

In [7] Welch reports similar results using a voiscope [13] which displays a real-time trace of fundamental frequency against time on an oscilloscope, thus providing fine detail of vocal pitch accuracy. However, this system is not ideal for general use with singers as it is expensive and requires considerable induction into its use. The purpose of this paper is to describe a pilot study on a new singing ability assessment and development system which is based on the BBC microcomputer with a small hardware interface box (110 X 45 X 70mm) and menu driven software.

THE 'SINGAD' SYSTEM

The "SINGAD" (SINGing Assessment and Development) system [17] has been designed around the BBC microcomputer, since it is likely to find application in Primary and Secondary schools where this computer is ubiquitous. The main prerequisite of SINGAD is that the software be provided with a real-time indication of voice fundamental frequency. This is achieved by the use of a peak-picking device [14] which has been developed for use in (a) cochlear implants for the totally deaf [15] and (b) acoustic sinewave hearing aids for the profoundly deaf [16]. The device operates in real-time with no output smoothing and is pocket-sized and battery powered.

The design features inherent in the peak-picker also have an application for singing development and assessment. Firstly, feedback is available in real-time, and secondly the output from the device is not smoothed. This latter feature relates closely to the actual type of voice production of young/inexperienced singers as tentatively sung notes can often have 'broken up' or 'rough' pitch contours.

In the assessment phase, the computer generates up to ten randomly ordered sounds in one of two ranges (see figure 1), and after each sound the subject's vocal pitch attempt at imitating the stimulus is measured in Hz. The results are tabulated (see figure 5), and from these the comfortable range for a subject can be inferred as including those notes in the test to which a significantly closer sung value was obtained. Other statistics may be appropriate here, thus the data is stored on disk. On storing, the random order of presentation, which varies each time the test is run, is maintained to allow any ordering effects to be investigated if required.

In the development phase any sung input is represented as a dotted line on the screen, plotting the logarithm of fundamental frequency against time (see [18]). Each dot corresponds to a measured period, and for silence or non-voiced sung or spoken sounds, a solid line is produced at the foot of the screen (see figures 3 and 4). There are various options available to the user. Firstly the range of fundamental frequency displayed is adjustable to best suit the subject's range, from 8 available ranges (see figure 2). The bass and treble clef ranges (7 and 8) are for more advanced subjects. Secondly, picture targets are available either 1, 2, 3, or 4 pictures from a library of three picture sets (figure 3 shows 4 'space' pictures and a sung pitch trace), and they are plotted alternately into the upper and lower halves of the screen as one looks across it, to provide a zig-zag pattern. These screens can be 'juggled' to alter the position of the pictures. Finally a display which involves one picture with an associated note played by the computer is available (see figure 4), and if the vocal pitch response is pitched appropriately, the dotted line produced will go through the picture as in the figure.

PILOT STUDY OBJECTIVES

A pilot study on the SINGAD system [19] involving a total of 15 sessions with 10 children (5 of whom were tested twice) was set up with the following aims:

1) to validate the peak-picking hardware in general use with children and young adults;
2) to investigate the usefulness of the frequency ranges chosen in both the assessment procedure (figure 1) and the development phase (figure 2);
3) to suggest developments and improvements to the software in terms of both operation and user-friendliness;
4) to define a more rigorous SINGAD development protocol.

PILOT STUDY -- SOFTWARE AND HARDWARE VALIDATION

The first of these aims was investigated in a qualitative manner. Its purpose was to ensure that the device was generating an appropriate output over the large fundamental frequency range involved, i.e. embracing both adult males and children. Initial system verification was provided by an adult sample of trained singers who were able to imitate vocally the test frequencies within a few Hz, and were able to pitch notes to hit the picture at the appropriate point (see figure 4). Further support for the integrity of the system was provided on transfer to child subjects. The peak-picker itself has been the subject of extensive quantitative testing against a reference device [20].

The ranges employed in training were set up with reference to the pitches typically produced by poor pitched singers [21] which have been found to be (see figure 2 range 3) in the fifth between A(220Hz) and e(330Hz). Ranges 1 and 2 shown in the figure are designed to expand the screen range as the child's pitching abilities develop. As a result of the pilot work, it was decided to make range 2 the default since the protocol demands the use of spoken input prior to any sung input, and this octave range is better suited to the conversational speech of children. Ranges 4-6 were set up in the same manner as ranges 1-3, using as a starting point the fifth between A'(110Hz) and E(165Hz). Ranges 7 and 8 are for use with the treble and bass clef displays respectively.

There are two ranges, 'treble' and 'bass', available in the assessment phase (see figure 1). In each case the ten test notes used correspond to ten consecutive 'white' notes on a keyboard, and they have been chosen to cover the range used in poor pitch subjects, then extended upwards.

PILOT STUDY -- DEVELOPMENT PHASE PROTOCOL

The definition of a development phase protocol was the prime aim of the pilot study. The major finding from this initial work was that the children had difficulty with the concepts of 'high' and 'low' in relation to their pitch production (confirming other research into polysemous vocabulary e.g. [22] [23]), thus some method had to be found to develop a link between the vocal pitch and its screen display, making pitch movements conscious. Typically, encouragement to sing 'higher' would elicit an unchanged pitch sung more loudly or with an associated lifting of the peak-picker box, and 'lower' would result in a steady pitch sung softer or accompanied by a lowering of the box. However, direct imitation of the experimenter's vocal pitch enabled subjects to achieve the appropriate effect on the screen, but they were unable to continue to do so without the preceding auditory model. Thus a protocol was developed to allow for this.

This initial task in the development phase consisted of a blank screen on which the trace appeared alone, and the child was asked to imitate sounds from everyday life and to describe the resulting alterations in the shape of the trace. The descriptions were developed interactively without any direct auditory model being given, in order to encourage the production of particular shapes of the line on the screen (e.g. a mountain, a steep slope, a straight road) thus removing the reliance on auditory model imitation. The ability to alter vocal pitch at will, thus developed by reference to the visually fedback shapes, rather than by the use of descriptions (high, low, level etc.) of pitch change. Only when some competence had been achieved did the development phase move on to include visual targets as correlates of auditory space. At first just one picture was used, others being added as pitch control developed, i.e. the target being 'hit' (see figure 3). Then the development phase concluded with a joint visual and auditory target (see figure 4). Succesful vocal pitch matching of the auditory input ensured success in hitting the target.

PILOT STUDY CONCLUSIONS

The pilot study has shown, in the terms defined at the outset, that:

1) The peak-picker seems to operate quite satisfactorily with the 10 children so far tested. It is known to operate appropriately for a speech input [20] and this was the first more rigorous trial of its applicability to singers.
2) The ranges utilised in the two phases of the program appear to be appropriate for the abilities so far investigated, and the options provided in the development phase (see figure 2) appear to give enough flexibility to enable all subjects to achieve an output on the screen in their comfortable vocal pitch range.
3) Software improvements have been required at various stages of the pilot study for reasons of usefulness, flexibility and user-friendliness, and these will no doubt continue as long as the system is used.
4) The interrogation of the development protocol became the prime task of the pilot study since initial ideas in this area were found to be problematic (see above). Play concepts drawn from child development

studies [24] have been used to help define these stages. The currently preferred SINGAD protocol consists of:

a) an initial assessment phase;

b) work with a blank screen to establish pitch control skills;

c) work with visual feedback to develop pitch control skills using 1-4 pictures from the SINGAD library;

d) work with visual and auditory feedback to develop pitching skills;

e) a final assessment phase.

In the terms discussed above, section (b) of the protocol makes use of 'free play' and sections (c) and (d) make use of 'structured play'.

DISCUSSION AND FURTHER WORK

Use of the SINGAD system with children has shown promise for the future. It is expected that improvements in vocal pitch matching ability would be achieved over a prolonged period of use in the free and structured manner outlined above, and that this improvement could be monitored session by session using the assessment results gained at each session. Further work will be carried out with the aim of demonstrating this for a number of subjects, both children and adults.

As with any system involving a evolving software component, there is room for improvement. In this system the major area which could benefit from software enhancement is the first development phase (b) above. It is hoped that control of various game-like displays can be set up, for example a car going along a road in which the road is defined up, down, or straight across the screen and appropriate pitch control keeps the car 'on the road'. The computer could score the game giving a number of points for the time spent 'on the road' and taking points away for time spent 'driving more carelessly'. In this way children could perhaps work in pairs, a practice which is encouraged in schools, and there would be some stimulus for improving vocal pitch matching ability in a competitive environment.

This system may also find favour with speech therapists, and it will be evaluated and subsequently tailored to meet their needs. In such an environment the game outlined above could be extended to use 'roads' which are shaped so as to match the intonation contours to be developed. Thus the game element would play a part in the development of intonation production skills.

It is also suggested that SINGAD could find application with student singers who are developing particular skills in: vibrato; note onset and release; interval pitching; scales; and exercises in note relations; leaving more time for the professional teacher to develop other skills, such as the development of non-western singing techniques.

Thus the SINGAD system is believed to have a considerable usefulness in a variety of disciplines, and it is hoped that these can be developed. The intention is to aim for a system which is on the one hand easy to use, but on the other flexible enough for the users to develop their own preferred protocols.

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Figure 1: Treble and Bass assessment ranges - 10 notes for each.

Figure 2: The 8 ranges used in the development phase.

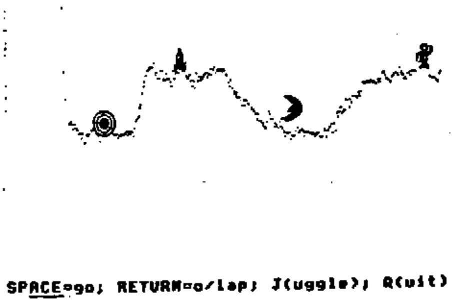

Figure 3: 'SPACE' pictures with a pitch trace.

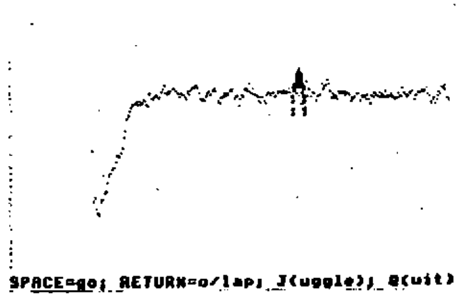

Figure 4: Auditory development screen - note played at picth required to 'hit' racket as shown.

Specimen results table for a child

Test (Hz)	Sung (Hz)	Oct dif	S/tone dif
335.800	340.483	0.020	0.240
449.300	429.369	-0.065	-0.786
399.800	408.330	0.030	0.365
503.700	305.904	-0.719	-8.634
266.300	267.237	0.005	0.061
355.900	355.999	0.000	0.005
251.300	255.037	0.021	0.256
299.900	297.442	-0.012	-0.142
224.300	226.449	0.014	0.165
533.900	287.853	-0.891	-10.695
	MEAN DIFS:	0.178	2.135

Figure 5: Example assessment results table.